LBNL CDF Program at the Tevatron

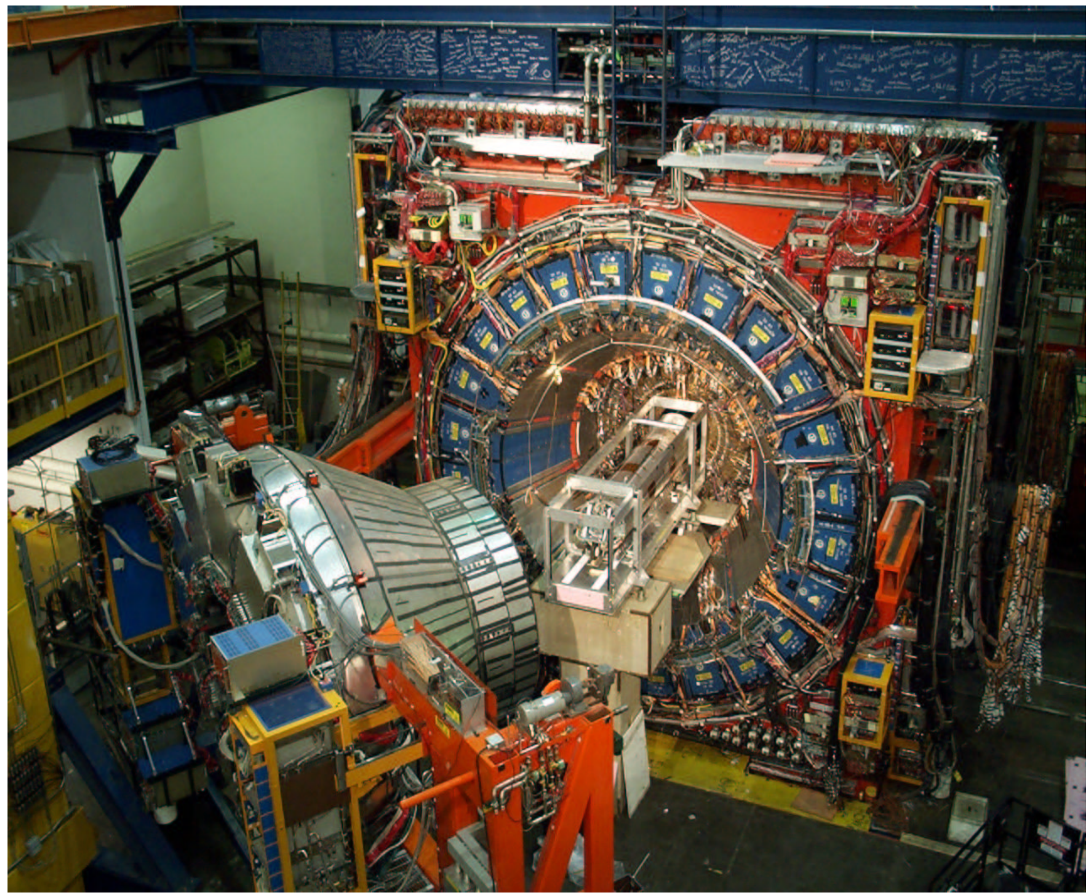
Angela Galtieri

LBNL DOE Review
May 7−8, 2002

Outline

- Accelerator Status
- The CDF II Detector
- LBNL Group Responsibilities
- Silicon Detectors
  - Run IIa
  - Run IIb
- COT+TOF
- Current Activities
  - Tracking
  - b−tagging
  - Electrons
  - Jets
- Physics Program
  - B Physics
  - EWK (W/Z/Top)
  - Higgs
  - New Physics
- Summary

CDF Detector

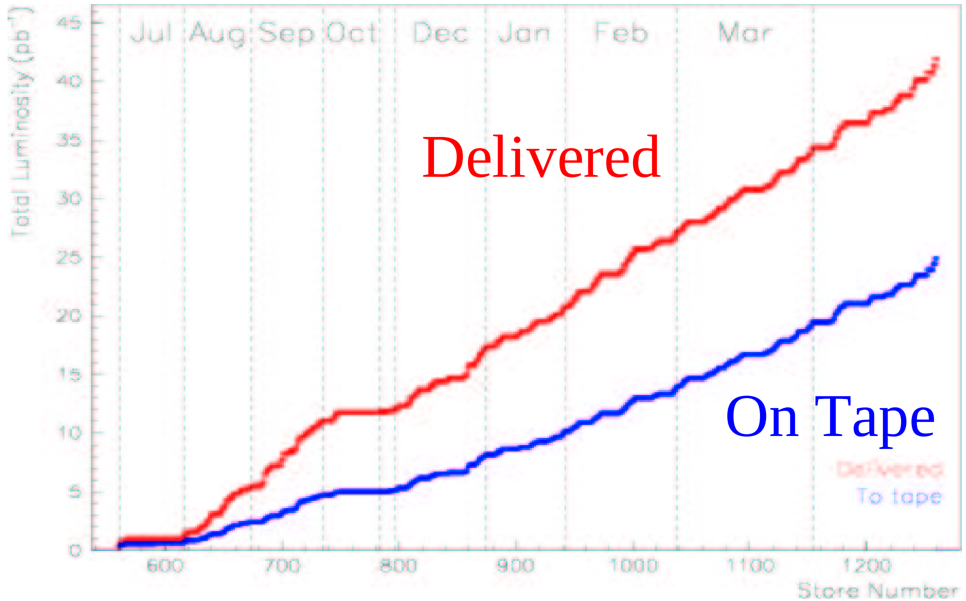


installing silicon tracker, prior to detector roll−in

Run II Accelerator Status

- Run II Upgrades: $5 \times 10^{32}\ cm^{-2}\ s^{-1}$
- Main Injector (2001)
- Recycler (2002):
  recover antiprotons
- Bunches
  initially 36x36 at 396 ns
  ultimately 132 ns
- $\sqrt{s} = 1.96$ TeV
- Current performance
  $1.9 \times 10^{31}\ cm^{-2}\ s^{-1}$
- Integrated luminosity
  42 pb^{-1} delivered
  CDF: 25 pb^{-1} on tape

Luminosity from CLC, May 5, 2002



Integrated luminosity about a factor 2 lower than expected

The CDF II Detector

Tracking system is all new, new Plug Calorimeter, improvements to all the other detectors

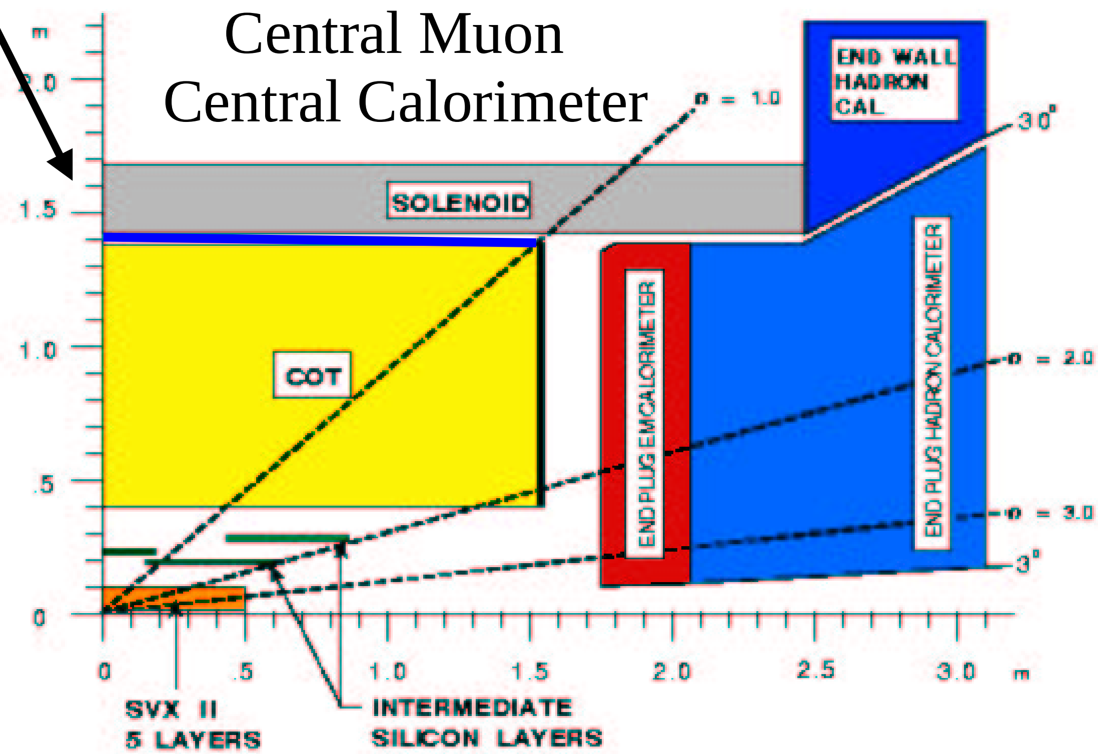
- New wire drift chamber, COT (96 layers)
- Time of flight system
- New silicon system:

  Double sided sensors, up to 7 layers

  Covers to $|\eta| = 2.0$

  L00, added later, close to beam pipe (1.35 cm) for improved impact parameter resolution
- Silicon vertex trigger (SVT)
- New scintillating tile plug calorimeter extends to $|\eta| = 3.6$
- Larger muon coverage

TOF



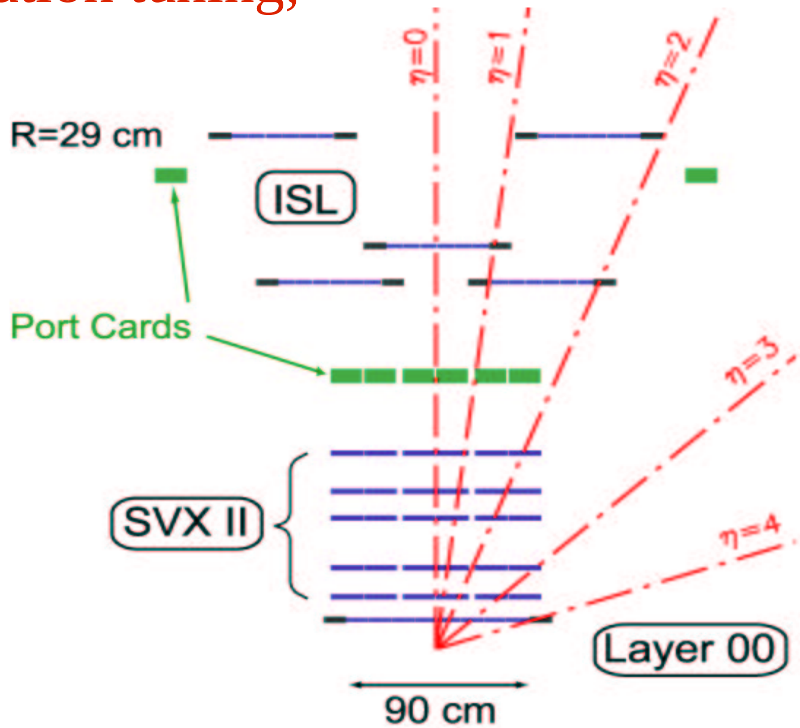
CDF II Status

Detector commissioning essentially complete (except for ISL)

- All detector systems taking physics quality data.

- Data being used to understand detector performance, optimize reconstruction algorithms, simulation tuning, early physics studies.

- Silicon system commissioning very close to completion:
  - L00 : 100% ladders integrated
  - SVX: 90% of ladders integrated, others need more work
  - ISL : 60% integrated. Remainder has cooling lines blocked, need long shutdown to fix



Members of the LBNL Group

Physicists−Staff (6.5 FTE)

P. Calafiura +
W. Carithers ++
R. Ely (retired)
A. Galtieri (Group leader)
M. Garcia−Sciveres*
C. Haber*
Y.K. Kim (UC Berkeley)
J. Lys (retired)
R. Miquel**
M. Shapiro* (UC Berkeley)
J. Siegrist* (UC Berkeley)
W. Yao**

Physicists−Term (5.5 FTE)

A. Cerri
A. Dominguez
J. Nielsen
B. Orejudos
L. Vacavant*
I. Volobouev

* ATLAS, ** PDG, + NERSC, ++ SNAP

Fellows (2 FTE)

C. Currat
M. Weber

Visitor

P. Maksimovic (JHU)

Grad. Students

T. Affolder ('96 Run II/I)
A. Connolly ('96 Run II/I)
G. Veramendi ('98)
H.C. Fang ('98)
E. Brubaker ('99)
H. Bachacou ('99)
A. Gibson ('00)
J. Muelmenstaedt ('01)

Undergrad. Students

L. Tompkins
B. Mishek

Engineers, Designers

B. Krieger
H. von−der−Lippe
J.P. Walder
E. Mandelli
B. Holmes

Leadership roles at CDF

- Marjorie Shapiro
  - **Offline Project Manager (March 98−October 2001)**
  - **Co−coordinator: CDF simulation group (since October 2001)**
  - **Co−coordinator: B physics group (since January 2002)**
- Young−Kee Kim
  - **Associate Project Manager (2000)**
  - **Associate Head of CDF Operations Department (to Dec. 2001)**
    - **in charge of commissioning**
    - **setting milestones, schedule and priorities**
    - **daily operations**
- Bill Orejudos
  - **Co−coordinator of the COT group**
  - **CDFII Operation Manager**
- Weiming Yao
  - **Co−coordinator : Higgs Physics group**
- Aaron Dominguez
  - **Co−coordinator: b−tagging group**
- Lina Galtieri
  - **Co−coordinator: Jet corrections group**
- Greg Veramendi
  - **Co−coordinator: high Pt Electron Task Force**

LBNL Contributions to CDFII

I. Construction

- Silicon detectors
  - SVX3 chip (co−design with FNAL), test, probe
  - hybrids for L00, SVXII, ISL
  - associated electronics
- COT
  - inner cylinder, field sheets
  - conceptual design of alignment
  - time calibration system
- TOF
  - Study laser calibration system
  - Install fibers, online monitoring

II. Commissioning

- Associated Project Manager (YK Kim)
- COT Commissioning (Orejudos)
- Silicon cabling to detectors, testing (Affolder, Dominguez, Nielsen)

III. Detector Operation (ongoing)

- CDF II Operation Manager (1 year)
- Develop and maintain SVXMON
- Develop and maintain DPED calibration
- Online data monitoring software (YMON)
- COT calibration

IV. Computing and software

- Project Manager (M. Shapiro)
- Codgen for relational data bases
- Data handling software for early tests
- Muon reconstruction software

- Ongoing responsibilities
- Simulation co−convener (M. Shapiro)
- MC generators :

  ISAJET (L. Galtieri)

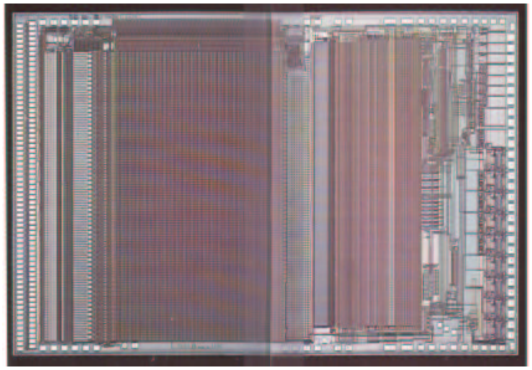
  HERWIG, Wbbgen (J. Lys)
- Silicon geometry (A. Dominguez).
- Passive material (L. Vacavant)

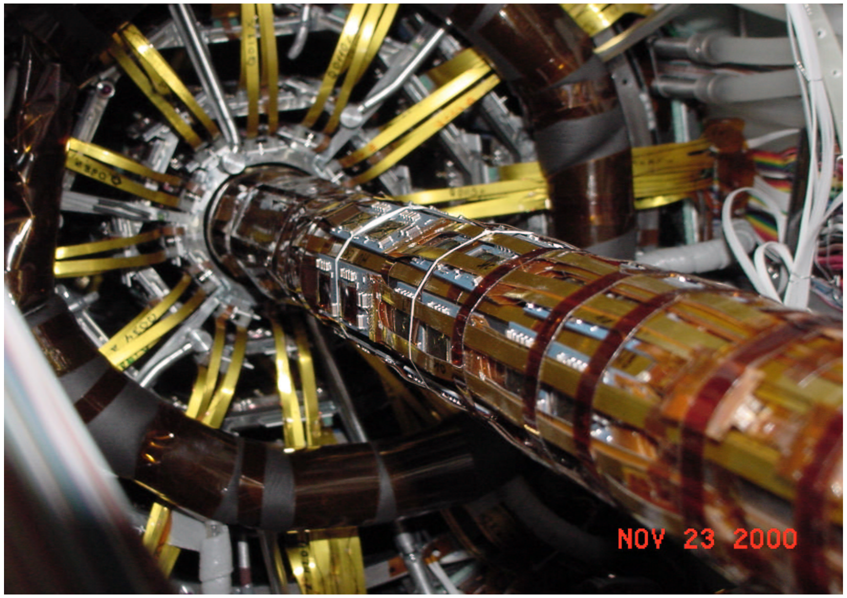
Contributions to Run IIa Si Construction

M. Garcia−Sciveres, C. Haber, I. Volobouev, R. Ely, T. Affolder, A. Connolly, A. Dominguez and many others

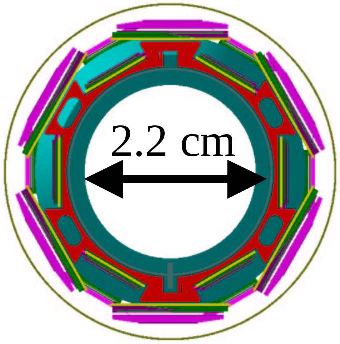
- SVX3 chip: co−design with FNAL test, probe 248 wafers, 20000 chips
- Hybrids : SVXII + ISL+ L00 (13 types) design, assembly, test, burn−in
- Associated electronics: port card design; mezzanine card design, construction

SVX3: deadtimeless chip

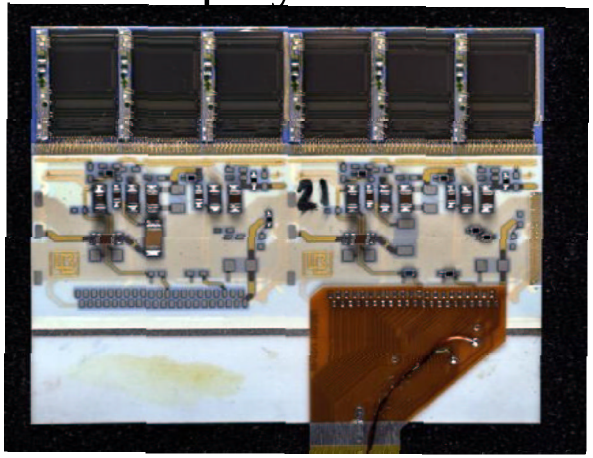




L00 on beam pipe



Six−chip hybrid for L3



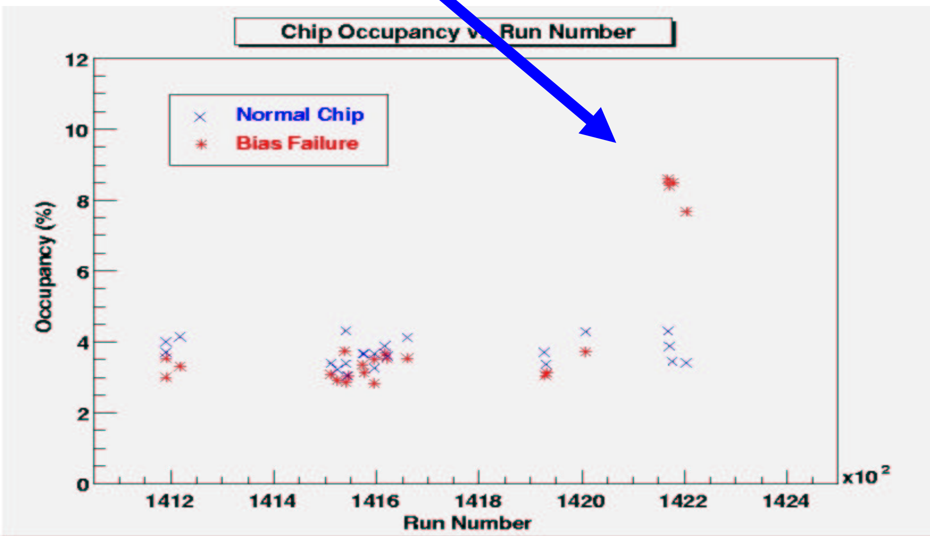
Responsibilities: Silicon system

Online monitoring: I. Volobouev, H. Bachacou

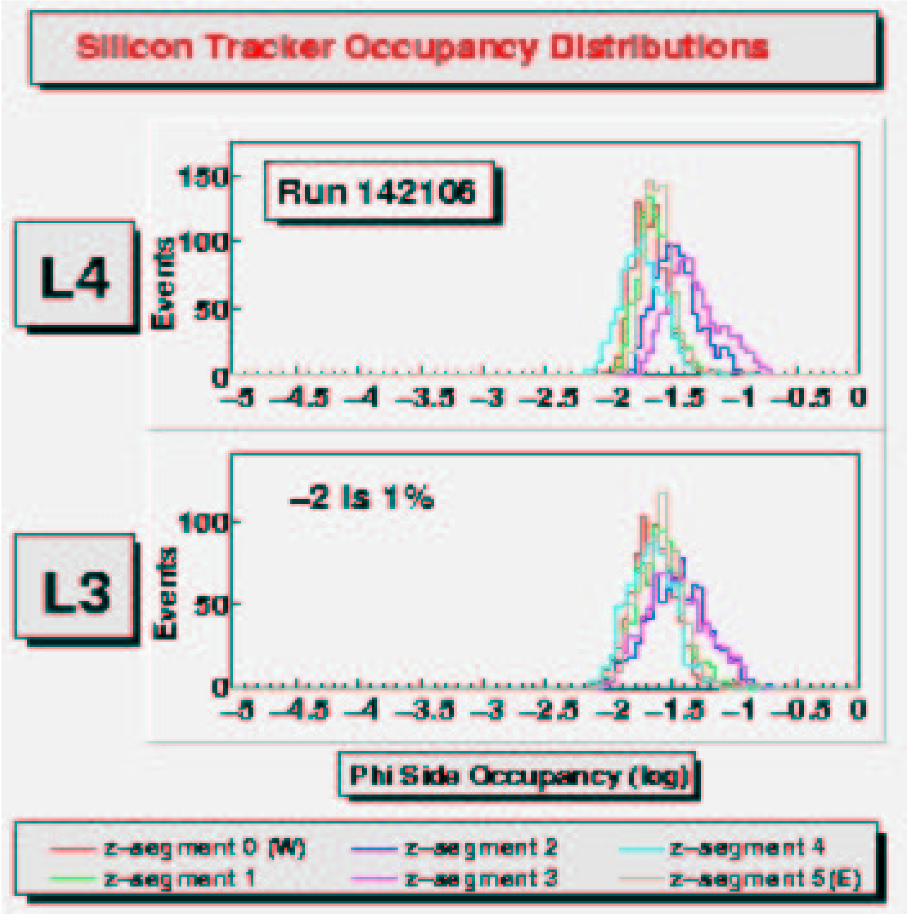
The 720000 channels of the Si system are monitored. The history of each channel is important to uncover problems.

- Very important tool during early stages of commissioning

Monitoring system keeps track of developing problems



Occupancy for the 6 half−barrels



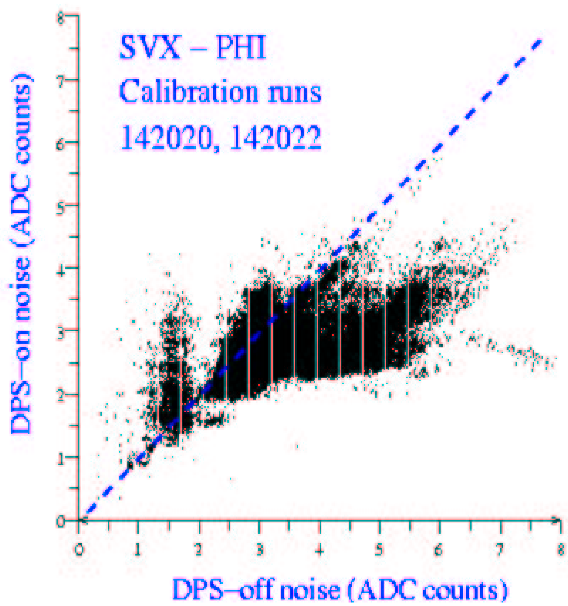
Responsibilities: Silicon system

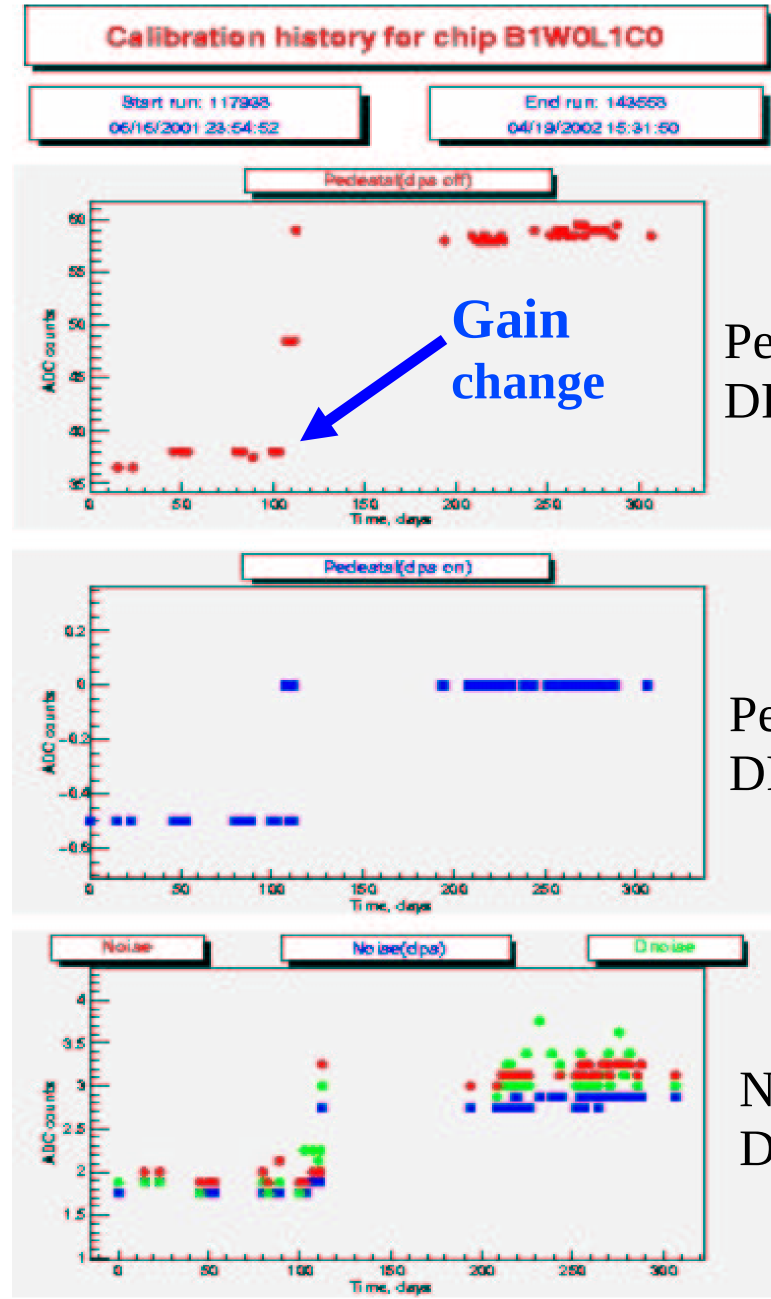
Calibration: Volobouev, Nielsen

Offline silicon calibration (4/30/02)

L00	12.8K/13.8K	channels	92.6%
SVXII	346.6K/405.5K	"	85.5%
ISL	152.5K/303.1K	"	50.3%

Important feature of the SVX3 chip:
Dynamical Pedestal Subtraction
reduces noise considerably





Pedestals DPS off

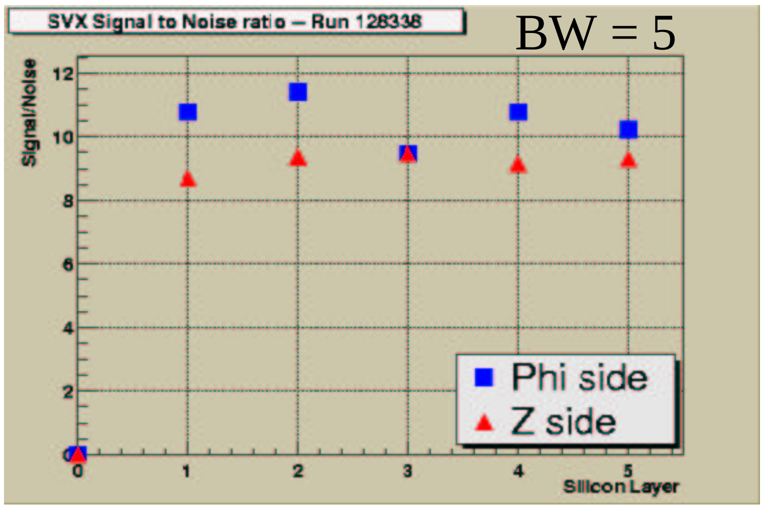
Pedestals DPS on

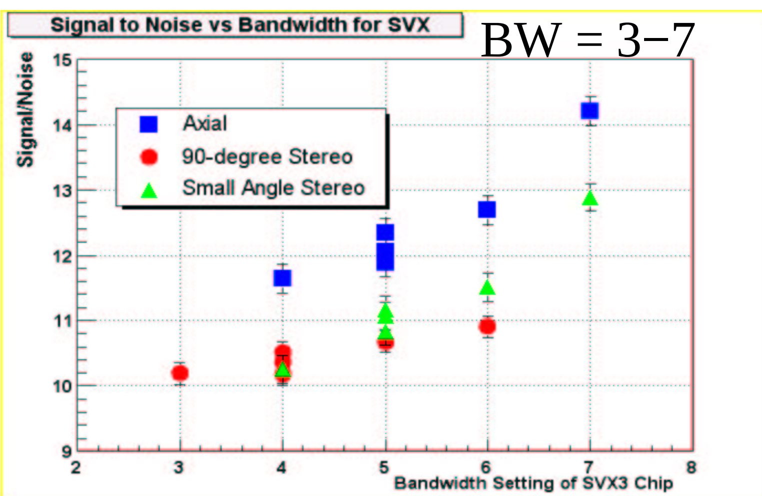
Noise DPS on

Responsibilities: Silicon system

Si performance optimization: Dominguez, Nielsen, Yao

Measured signal to noise in all layers and as a function of Bandwidth



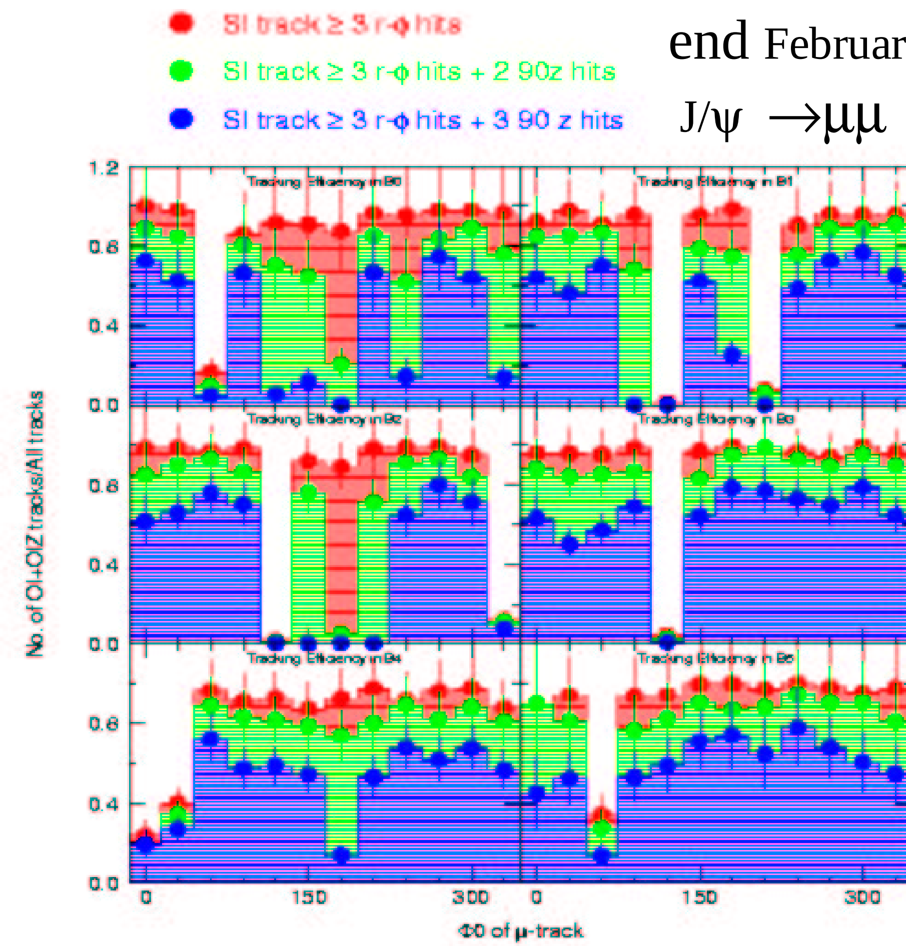


- Efficiency for finding tracks with at least three SVXII hits.

  Eff = 0 for ladders not yet turned on

end February

$J/\psi \rightarrow \mu\mu$



Weiming Yao with Mary Bishai

Impact Parameter Trigger SVT

Contributor to SVT hardware: A. Cerri

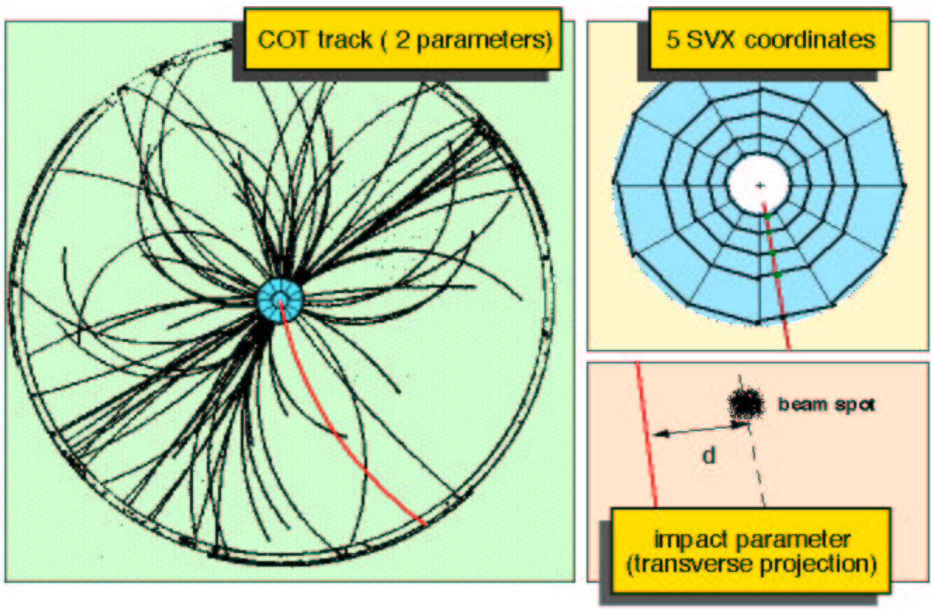
L1: COT track (XFT) with P_T > 15 GeV/c

L2: SVT combines COT track with Si hits

4/5 SVXII hits required (r−φ).

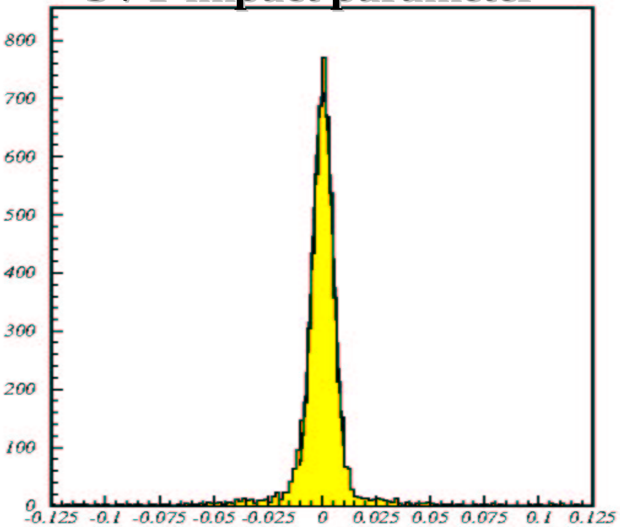
2 tracks P_T> 2 GeV/c and

impact parameter > 100 μm



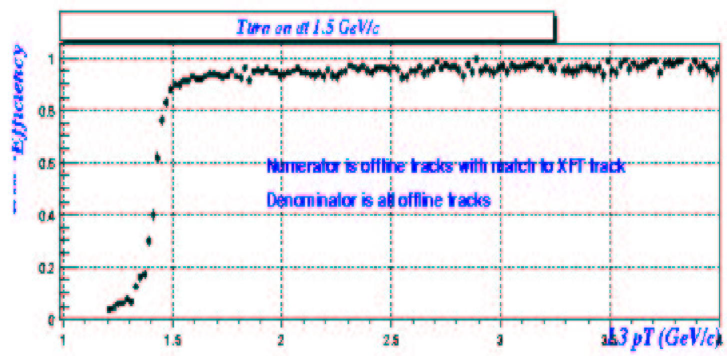
σ= 48 μ m including beam spot spread of σ=33 μm

SVT impact parameter



(Cerri)

XFT efficiency−vs− PT

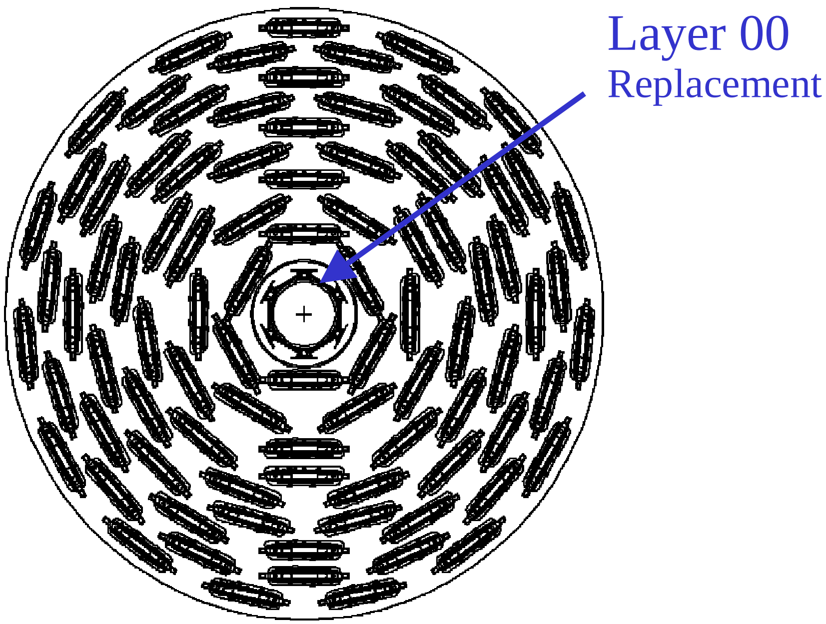


(Contributions from Veramendi)

Run II b Silicon Tracker Upgrade

M. Garcia−Sciveres, C. Haber, M. Weber, W. Yao, L. Galtieri (physicists), A. Gibson, B. Mikesh (students)

- For high luminosity run much of silicon tracking will not survive.
- CDF plans a change over to new silicon in 2005 with minimal interruption of running
- Simplified construction and assembly. Single sided detectors.



– Most of tracker based on single "stave" design. All modules are the same, except for L0 (on the beam pipe)

- LBNL group active participant since early 2000 when a CDF working group was established
- Initiated and led replacement of SVX3 chip with 0.25 μm SVX4, same functionality as SVX3
- Proposed baseline stave design, electrical prototyping underway
- Prototype hybrid in fabrication
- Contributed to simulation and Run IIa studies of 90^{o} performance

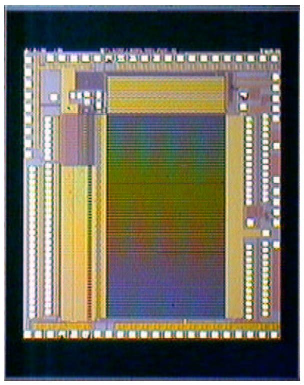
Contributions to Run IIb Silicon

SVX4 chip

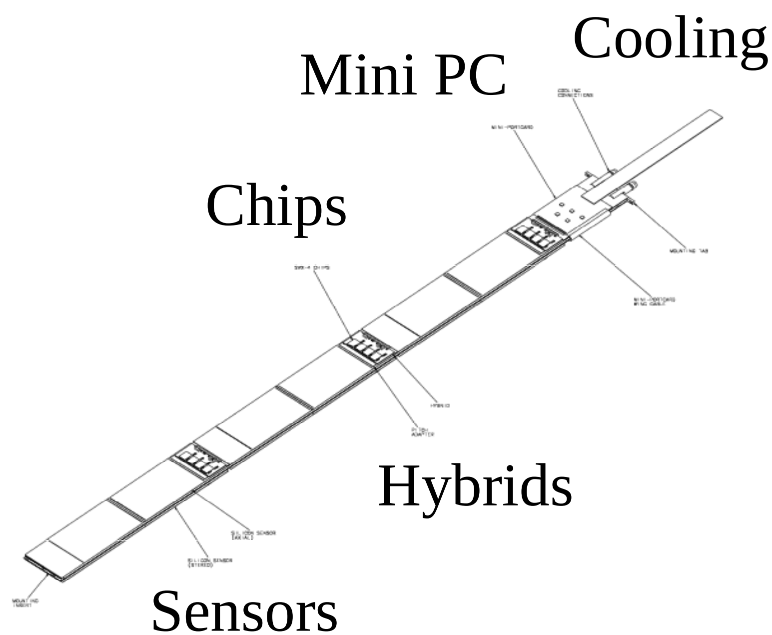
- LBNL−IC group leads SVX4 chip design (with FNAL and Padova)
- Chip to be used by both CDF and D0
- Extensive radiation studies of the SVX4 test chip (2000) and transceivers
- Complete simulation of SVX4 chip performed at LBNL
- Engineering run of full chip submitted on April 1, 2002

Test chip (2001)

Full chip due June 7



LBNL "stave" concept



66 cm long

Highly integrated electrical, mechanical & cooling unit.

Assembly line oriented design.

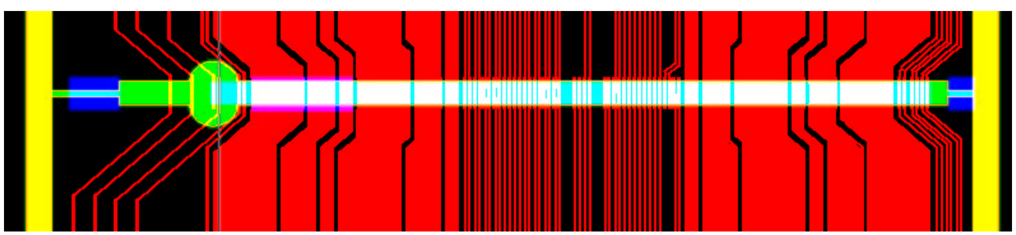
Contributions Run IIb Silicon

Hybrids Prototyping

- Based on technology used for L00 in Run IIa:
  simple design, minimize components and assembly steps.
- Only two types of Hybrids (13 types in Run IIa)

Stave Bus

- Stave contains integrated data/power bus serving all hybrids/side.
- Prototype ready for fabrication



Hybrid Production (??)

- Fabrication by one vendor of all ~1400 hybrids as opposed to 3 in Run IIa.
- Engineering Division at LBNL proposed Assembly & Test of all Run IIb hybrids.
- All Burn−in at UC Davis
- Will require some physicist help at LBNL
- Collaboration’s help may be available (Helsinki, Davis and others)
- Details and feasibility still under discussion.
- Reflection of general issue of Tevatron endgame and LHC startup

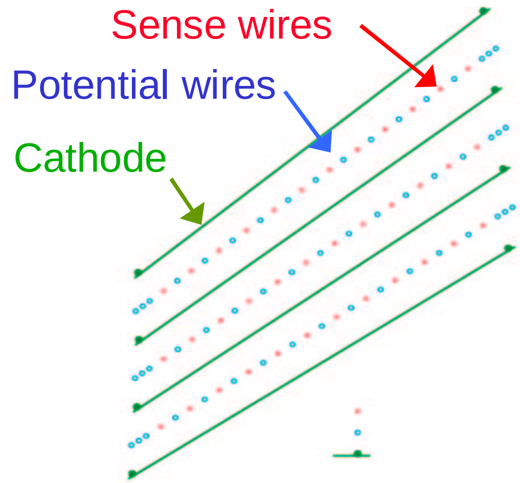
LBNL COT responsibilities

Y.K. Kim, B. Orejudos, T. Affolder, G. Veramendi, and others

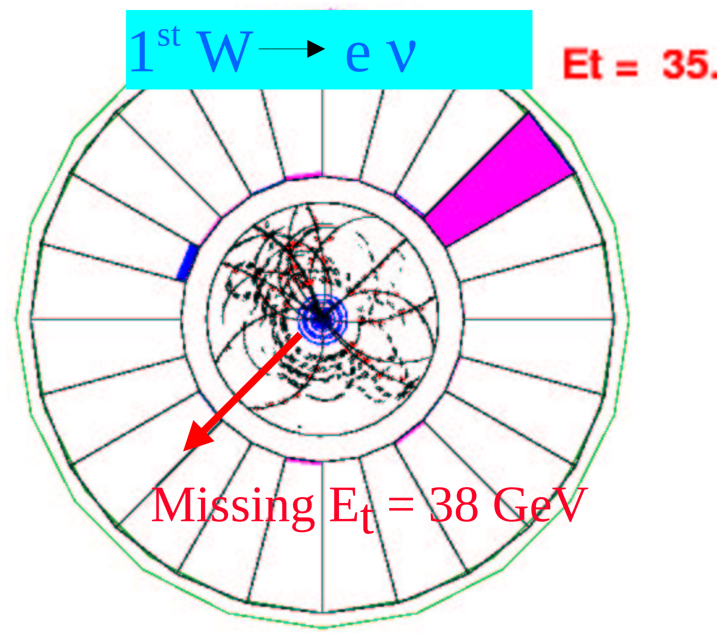
- Construction responsibilities
- Inner support cylinder
- Axial cathode planes: design fixtures, fabricate and test field sheets
- Electronics (Orejudos)

  Readout and calibration
- Commissioning

  Cabling (YK Kim)
- Operation (on−going)
- COT Operation co−leader (Orejudos)



- 96 wire planes
- (8 superlayers)
- 50% are 3° stereo
- Uniform drift
- (0.88 cm cell)
- Cells tilted by 35°
- 30,240 sense wires



Current LBNL Activities:
Prepare tools needed for physics

Many can be shared between High Pt and Low Pt physics

- Tracking
  - COT, Silicon calibration
  - Tracking algorithms
    - Outside−in tracking
  - Geometry
  - Momentum calibration
    - X−ray detector for dE/dx calib.
    - J/ψ , $\Upsilon\Upsilon$, Z lineshapes
- High Pt electrons
  - Creation of control datasets (W, Z)
  - Trigger efficiency studies
  - Electron ID (central & plug)
  - Energy calibration
- Jets
  - Energy scale
  - Algorithms
- b−tagging
  - Silicon
  - Soft e/μ
- Triggers
  - Level−1 tracking efficiency
  - Level−2 SVT
  - Level−3 filters
  - SVT Simulation
- Monte Carlo
  - Generation
  - Simulation

Tracking: basic ingredients

COT tracking studies: Y.K. Kim, L. Tompkins

H.Fang (data), L. Vacavant (simulation)

X−ray of the detector for p, E calibration

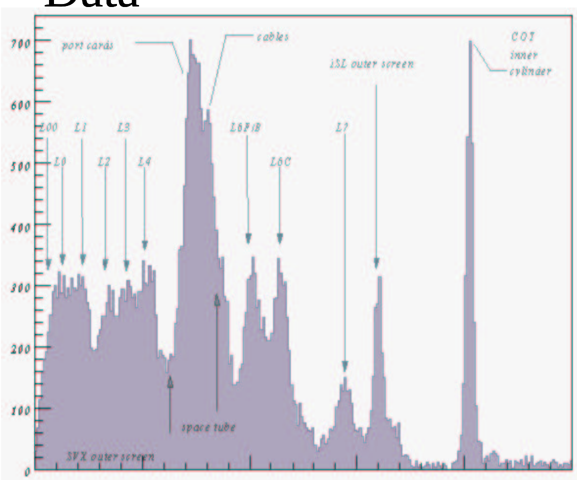
Study soft electrons, tracking, Creation of control dataset

Aaron Dominguez: silicon geometry

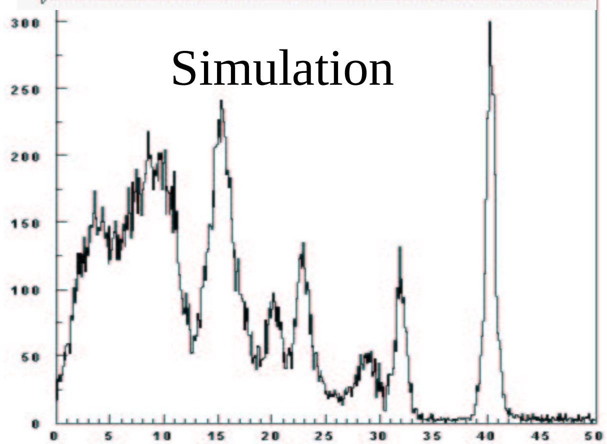
Detailed geometry of ladders, strips location

Readout order for all chips (L00, SVXII, ISL)

Data



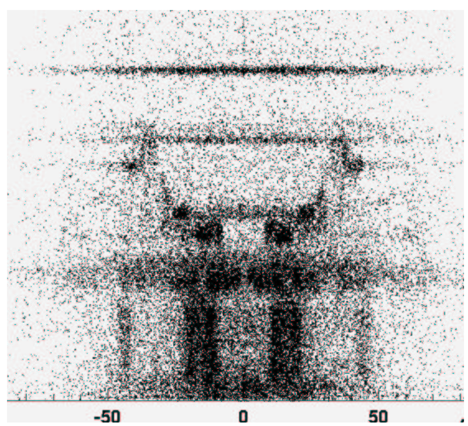
Simulation



Conversion radius (cm)

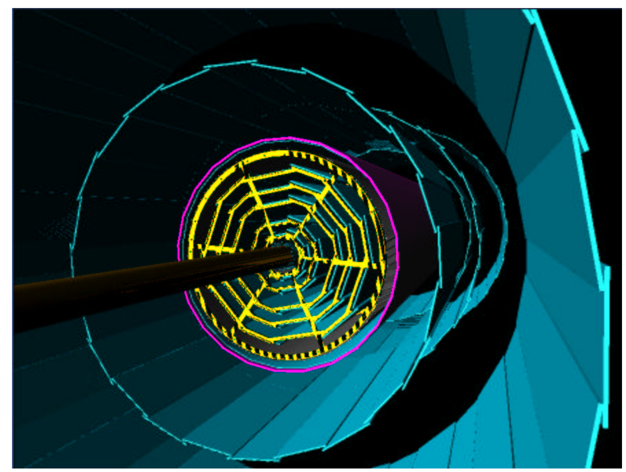
First try, good agreement

r vs. z view (data)



Shows:L00, SVXII and ISL layers, bulkheads, support cylinders, Port cards etc.

End view of SVXII



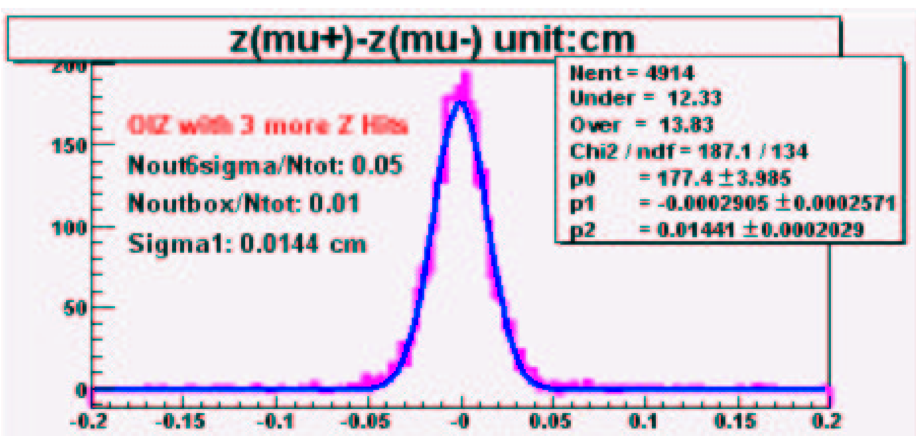
Silicon Tracking

- Weiming Yao : outside−in track reconstruction
  - Begin with COT tracks.
  - Add Silicon hits in r−ϕ and then z.
  - Resolution improved (no dE/dx yet)

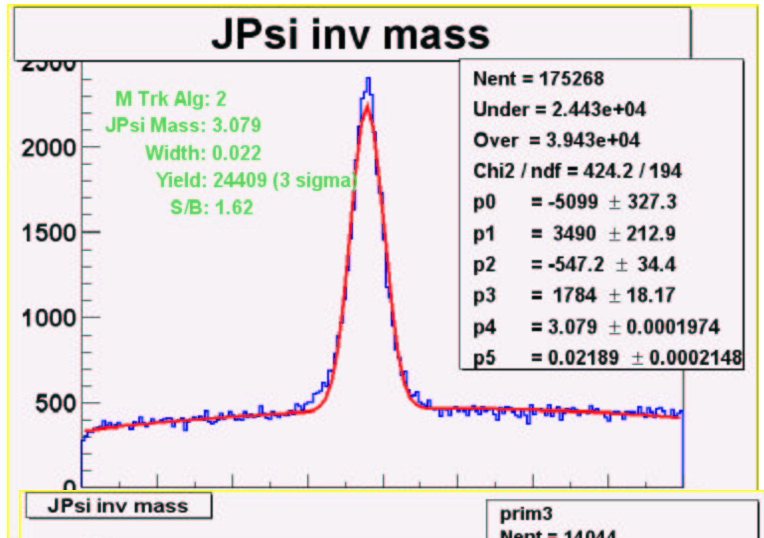
Hits	Mass(GeV)	Width(MeV)
COT only	3.079	22
COT+SVX	3.082	16

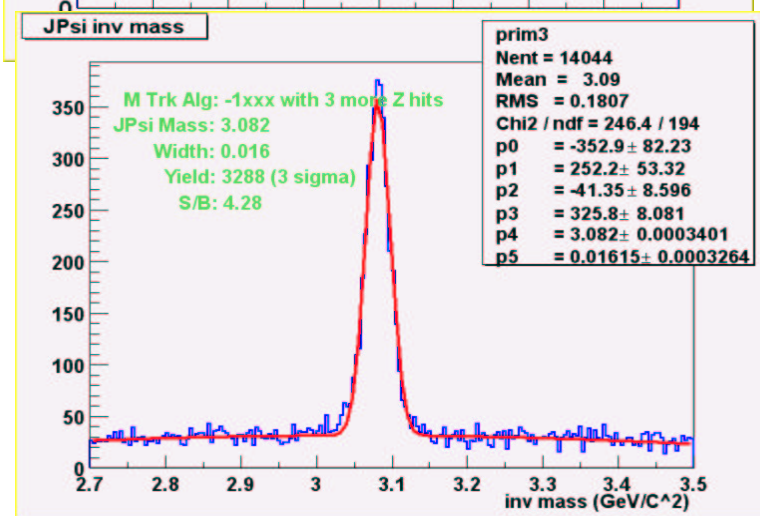
Require at least 3 hits in z

$\sigma(z) = 144\ \mu m \quad (P_T > 2\ GeV/c)$



CDF Preliminary, COT only





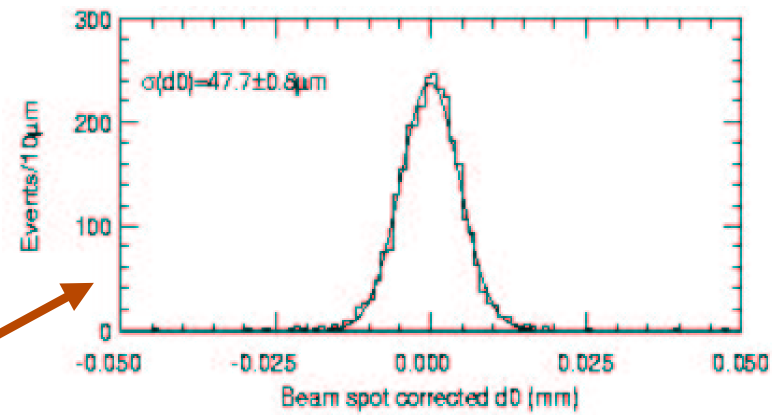
COT+ SVX Outside−in

b−tagging

A. Dominguez (co−cordinator of b−tag group), Yao, Bachacou, Deisher

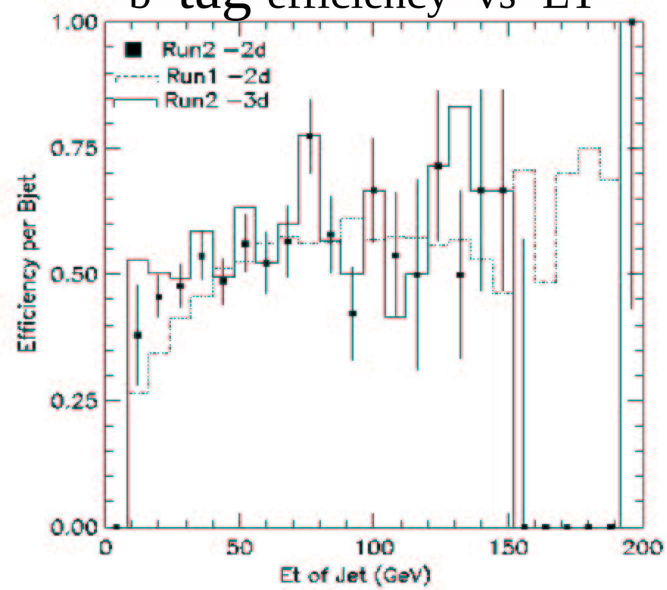
- Work just started, now that Silicon tracking optimization is converging.

- Impact parameter resolution, obtained with preliminary alignment, is 48 μm. J/ψ data was used.



- b−tagging efficiency expected to be higher than in Run I. Plot shows Run II efficiency for the Run I algorithm .

b−tag efficiency−vs−ET



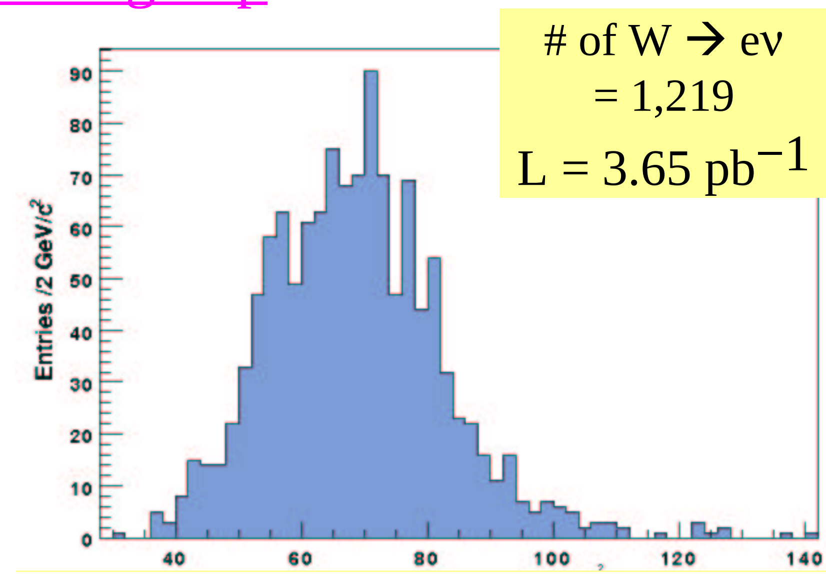
(Weiming Yao)

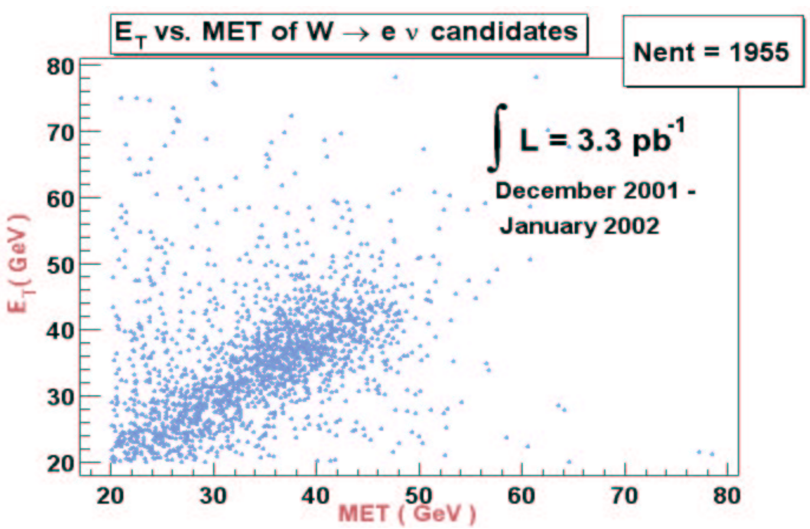
- Generator level studies have started. Work on primary vertex fitting being done

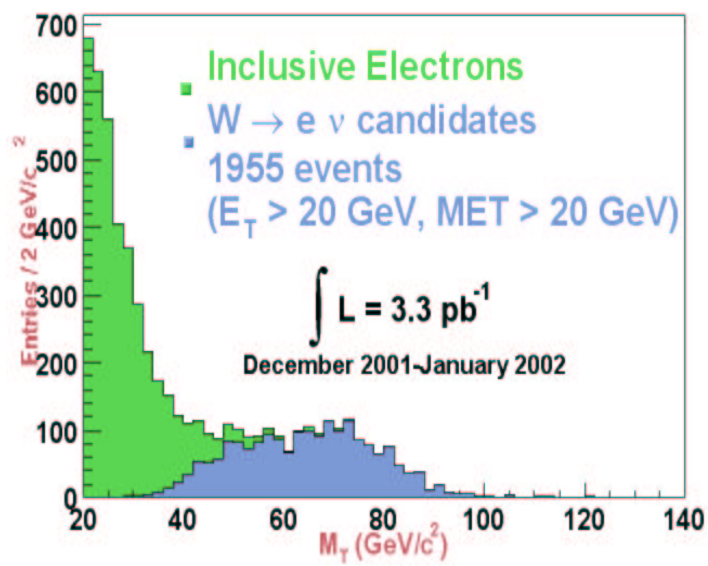
$W \rightarrow e\nu$ Sample Selection

- Greg Veramendi co−cordinator ETF group

- Level−3 filters
  - Electrons for W,Z
  - W: no track requirement
- tracking validation
  - trigger, offline tracking
  - Particle ID studies
- Kinematic cuts for W sample

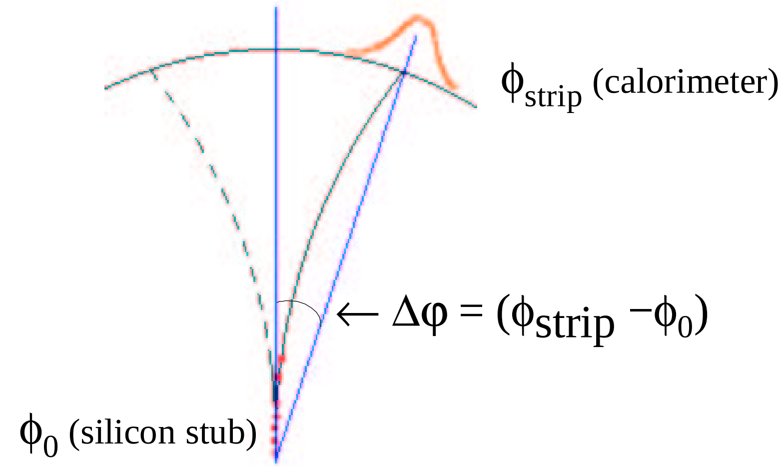






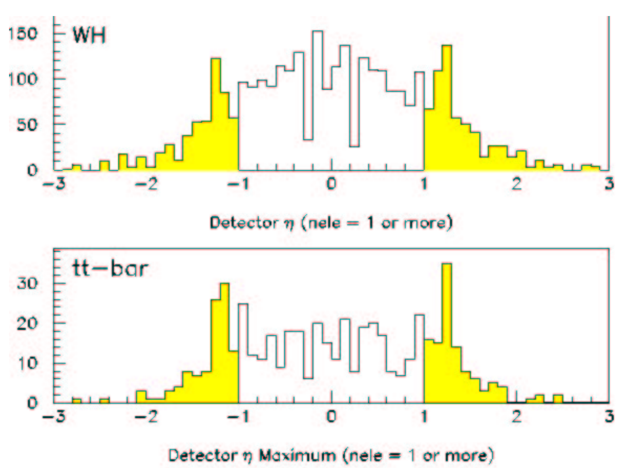
Electrons in the Plug

- Erik Brubaker, YK Kim, M. Garcia−Sciveres, Reygadas

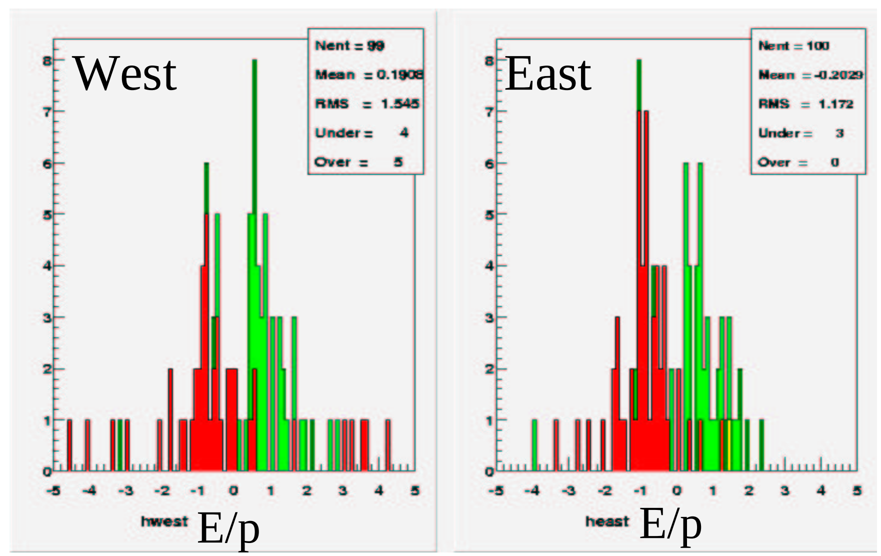


- **Plug ($1<|\eta|<3.5$) has large acceptance for important physics processes.**
- **Validate/fix basic software**
- **Develop electron ID using silicon hits.**
- **Use central electrons to test algorithm**
- **Align Plug to SVX. Find M(e+ e−) peaks.**

η distribution of electrons in Higgs and top events



Plug electrons after alignment



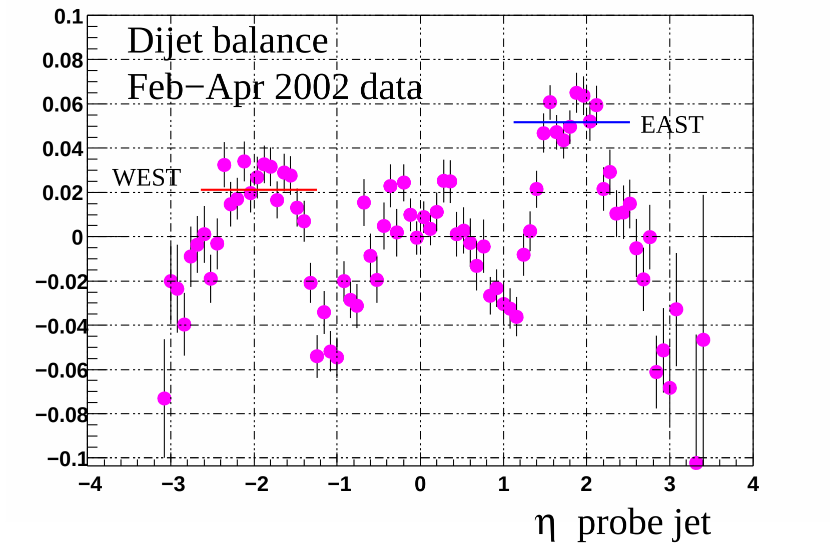
Jet E_T−Scale Studies

Galtieri (Co−convener jet correction group), Currat, Lys

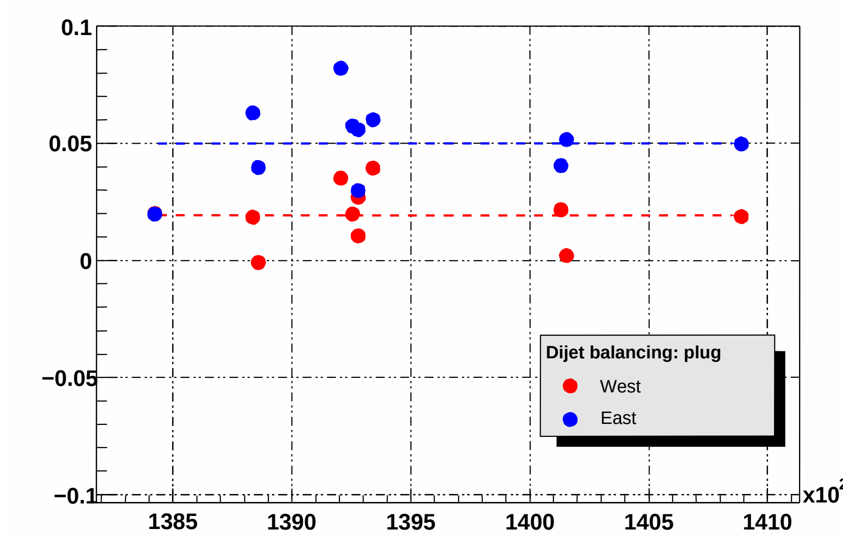
- Electron scale in CEM correct within 2% ($Z \rightarrow e\,e$)
- Hadronic scale agrees within 2% with Run I (MIP peak in $Z \rightarrow \mu\mu$)
- γ−jet balance can test **jet** scale, since EM scale is correct.
  MC studies needed to minimize QCD effects (K_T kick) (Jeremy Lys)

Preliminary result: absolute scale known within 6% in Central

For the plug we evaluate a correction relative to the central calorimeter by doing jet−jet balance (C. Currat).



Investigating a 3% systematic East−West energy difference in Plugs (Currat).



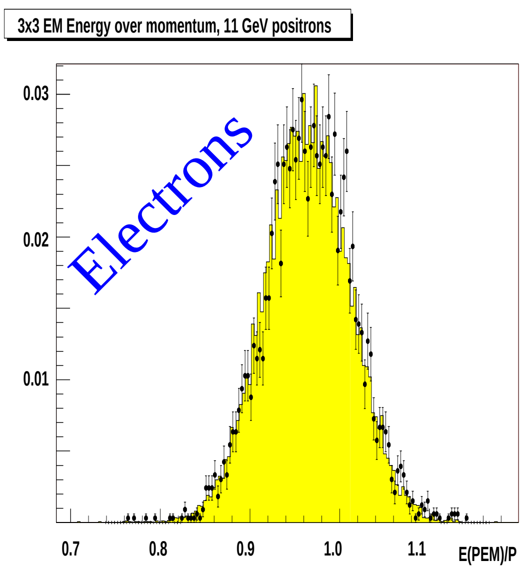
Calorimeter Simulation

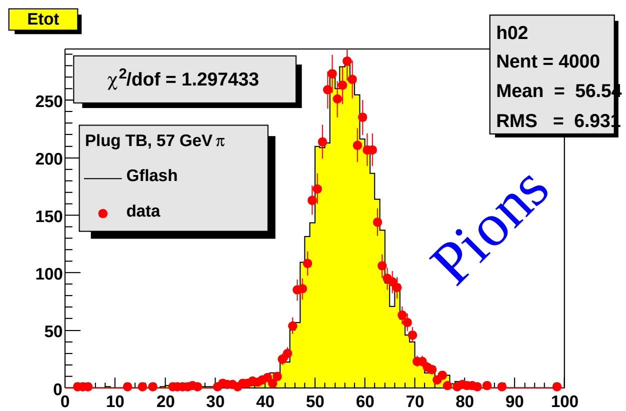
Charles Currat, Henri Bachacou, Erik Brubaker, Marjorie Shapiro

Tuning parameterized (fast) simulation – EM and hadronic calorimeter

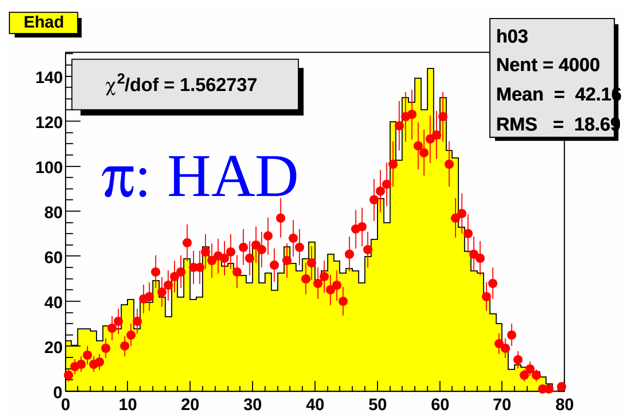
e.g. Electrons and $\pi^{\pm}$ responses : simulation vs test beam results

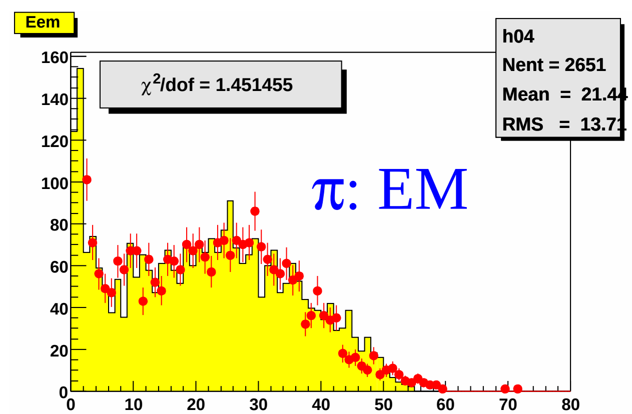
Very good agreement in 8−250 GeV range





For pions the EM and the HAD distributions are tuned separately





LBNL Group Physics Program

EWK/Top/Higgs Physics

- People : Bachacou, Brubaker, Currat, Dominguez, Garcia−Sciveres, Galtieri, Gibson, Kim, Lys, Nielsen, Orejudos, Siegrist, Veramendi, Volobouev, Yao
- Physics Interest :
  - M_{top}, M_W Measurements
    - The flagship analyses that will be done by the whole Top/EWK physics groups.
  - Top : V_{tb}, σ ratio, spin correlation, and W couplings
  - W,Z : A_{FB} at $s > M_Z^2$
  - Higgs Searches: SM and SUSY
  - SUSY Searches

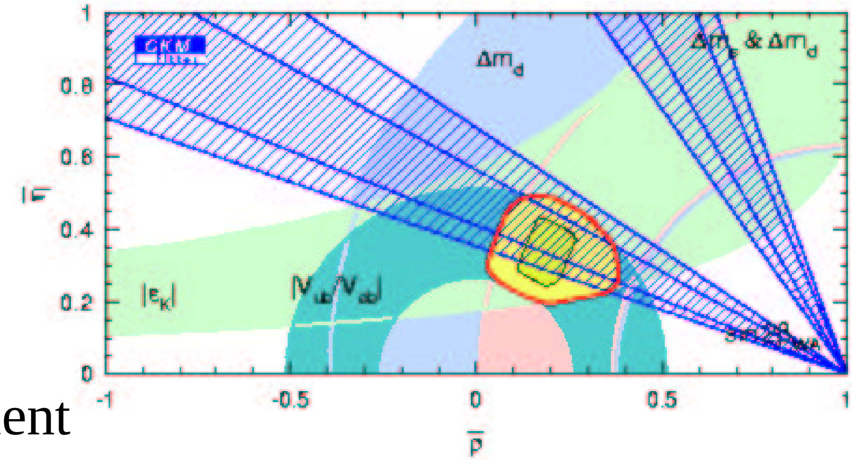
B Physics

- People : Calafiura, Cerri, Fang, Maksimovic (visitor), Miquel, Shapiro, Vacavant, Weber
- Physics Interests :
  - B_s mixing (major focus)
    - B_s lifetime (by−product)
    - B_s Kaon Correlations (by−product)
  - sin 2β
    - Analysis will be done by the whole CDF B−group.
    - LBNL contribution will be in tagging algorithms:
      - Soft electron/muon
      - Jet charge
      - Combined tagger

B Physics

M. Shapiro, Calafiura, Cerri, Fang, Miquel, Vacavant, Weber

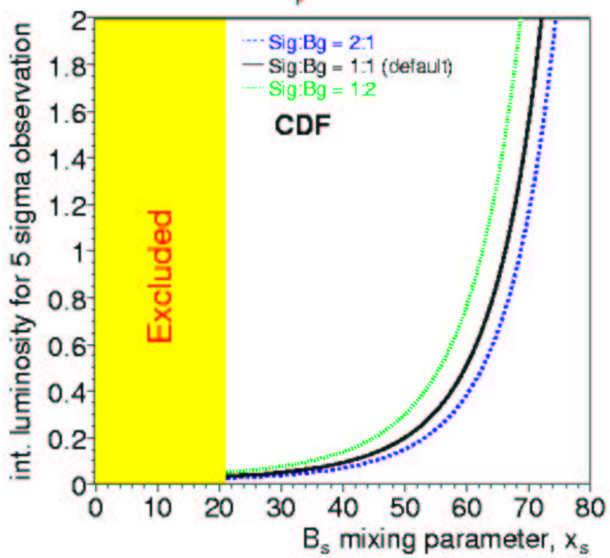
Improved tracking detector, Silicon vertex trigger (SVT) and large data samples give CDF a good opportunity to contribute to the study of the CKM matrix and CP violation.



- B cross section very large
- SVT allows study of the hadronic decays
- B_s, Λ_B, B_c unique to the Tevatron

In the next year, highest profile B measurement will be B_s mixing.

- Will use fully reconstructed B_s (i.e., $B_s \rightarrow D_s \pi$)
- Combine many flavor taggers
- Require a few hundred pb^{-1} for first measurement or world's best limit.
- With Run IIa statistics theoretically allowed range is fully covered.



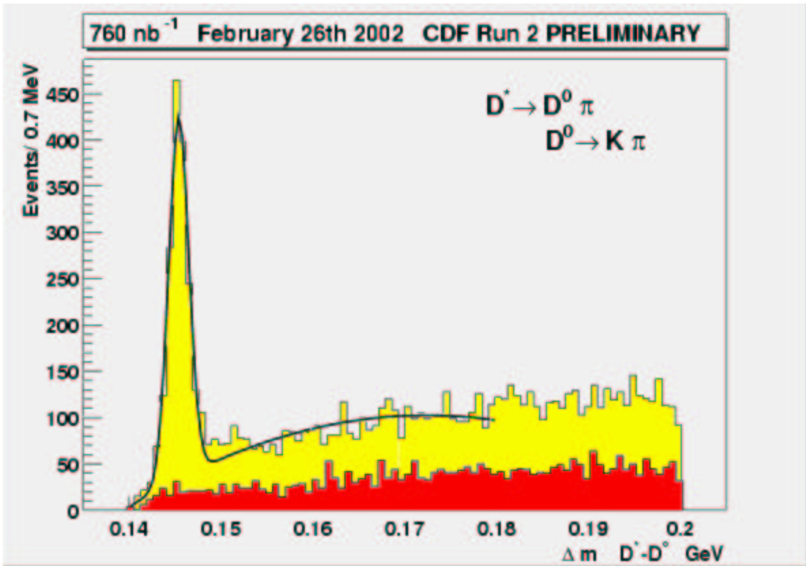
B Physics

CDF B Group Strategy for B_s Mixing

Optimize B Mass reconstruction for hadronic decays

- Measure b and c cross sections in triggerable P_T range
- Use Monte Carlo to model the signal (needs realistic detector and trigger simulation).
- Use sideband in data to model background

Reconstructed $D^* \rightarrow D\,\pi$



- Optimize Flavor taggers
  - Use *l* + SVT track trigger (high statistics)
  - Measure B_d mixing
    - amplitude of oscillations gives tagger quality (εD^2)
    - x_d measurement checks systematics on modeling of trigger and decays, as well as decay length reconstruction

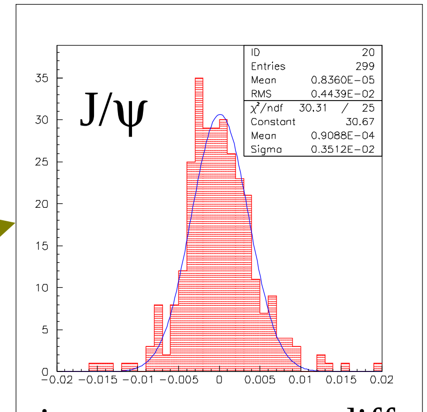
B Physics

LBNL Responsibilities

- B Group Co−convener (Shapiro)
- Co−leader Control Sample Task Force (Cerri)

Technical:

- Trigger Simulation and Validation (Cerri, Miquel)
- Flavor tagging optimization and lepton ID
  - Electrons (Fang)
  - Muon (Calafiura)
- Selection Criteria for Control Sample (Cerri, Fang) (needed for Flavor Tagger Optimization)

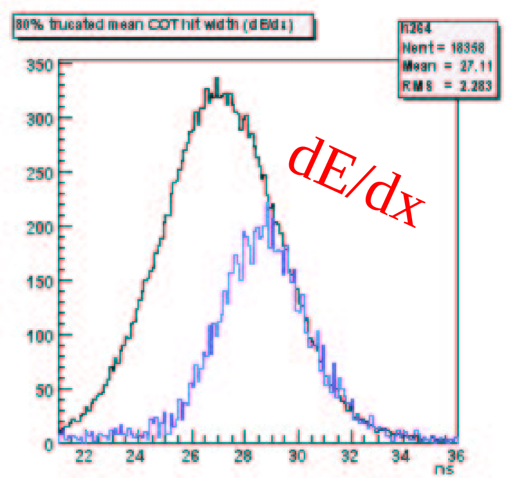


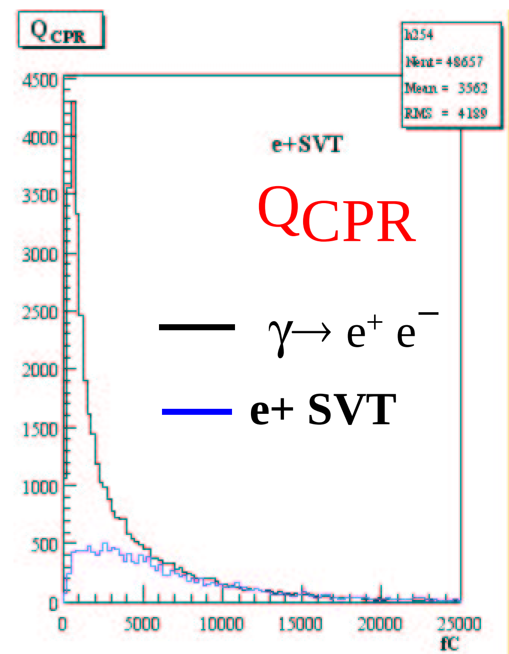
impact parameter diff.

J/ψ **used for evaluation of SVT efficiency (~ 72%)**

- Electron content in e +SVT sample found by comparing the CPR charge to electrons in the conversion sample.

- Use normalization in dE/dx plot and find 42% are electrons





(Fang)

EWK Symmetry Breaking

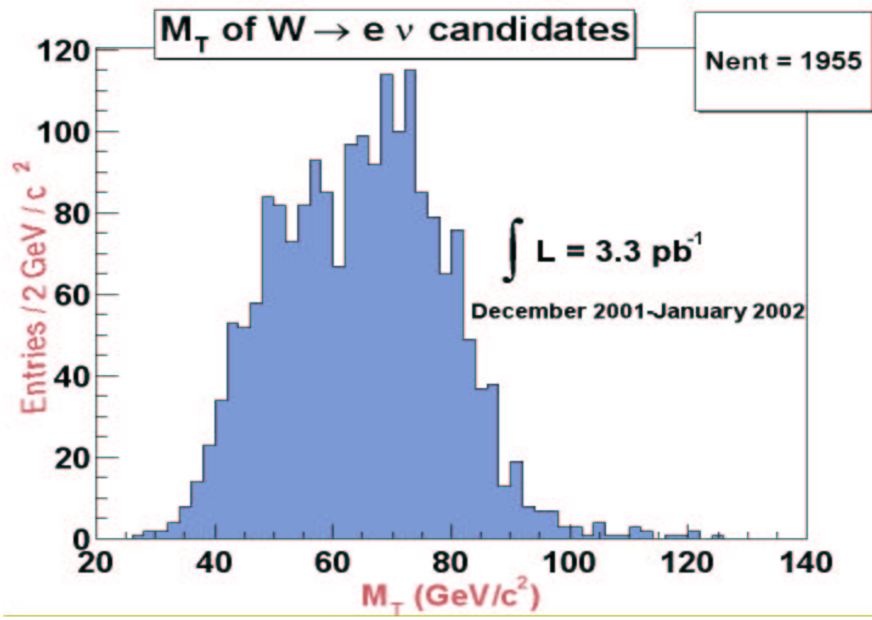
Y. K. Kim, Veramendi, Brubaker, Gibson, Tompkins

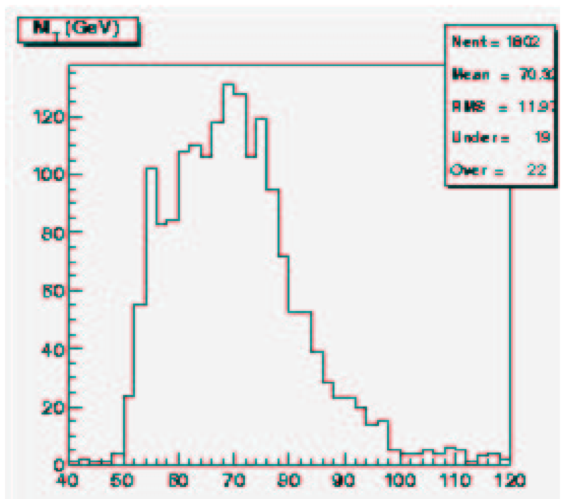
- Short term physics measurement:
  W lepton asymmetry.

- Will provide input to fitting Parton Distribution Functions, very important for precision W mass measurement.

- Longer term : participate in W mass measurement.

- This sample is also important for top quark studies: background and systematics

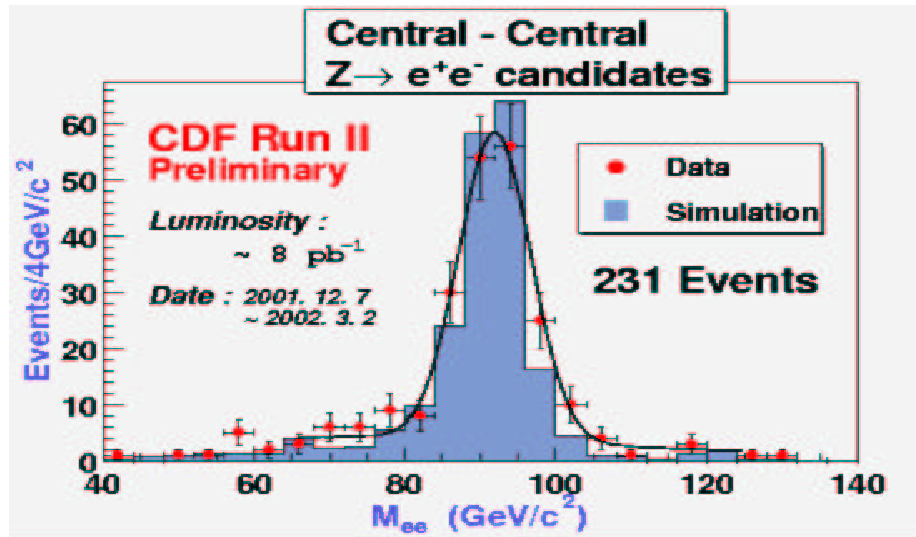


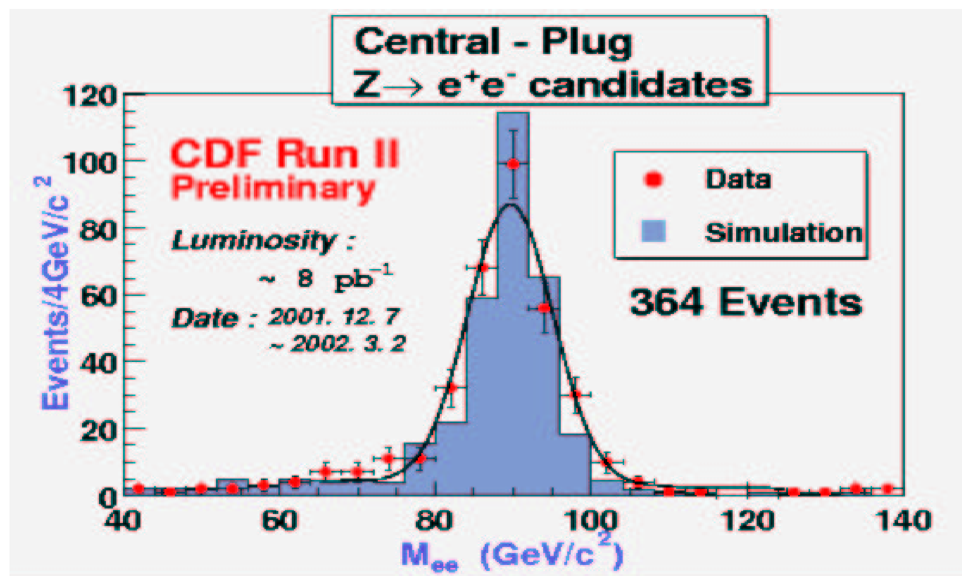


$Z \to e^+ e^-$ Asymmetry

Y. K. Kim, Veramendi, Brubaker, Gibson, Tompkins

- Asymmetry of $Z \to e^+ e^-$ can be measured at the Tevatron and it is expected to agree with that measured at LEP.
- For higher values of $M(e^+ e^-)$ the expected asymmetry is predicted by the Standard Model. Any deviation from predictions points to new physics
- Aim is to have a preliminary CDF result by summer Conferences

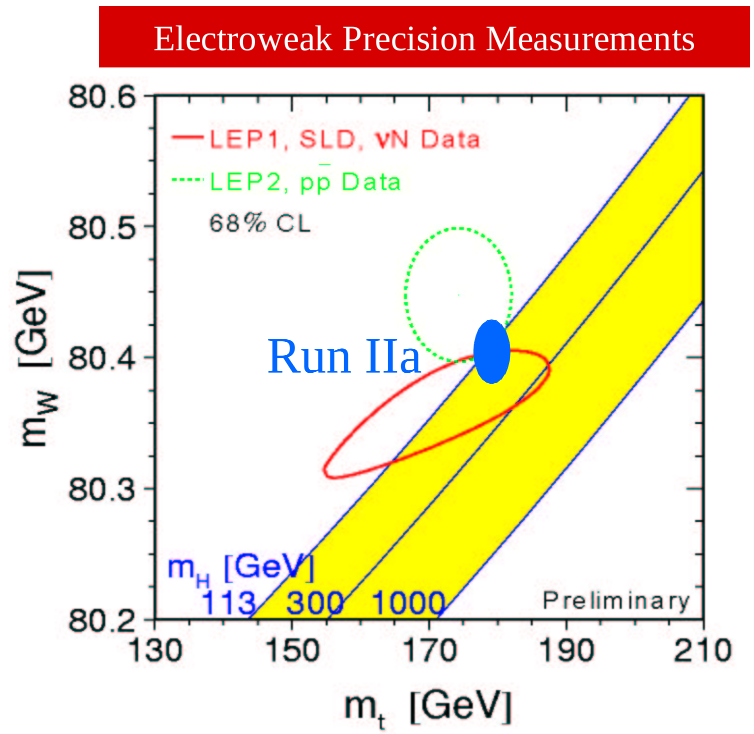


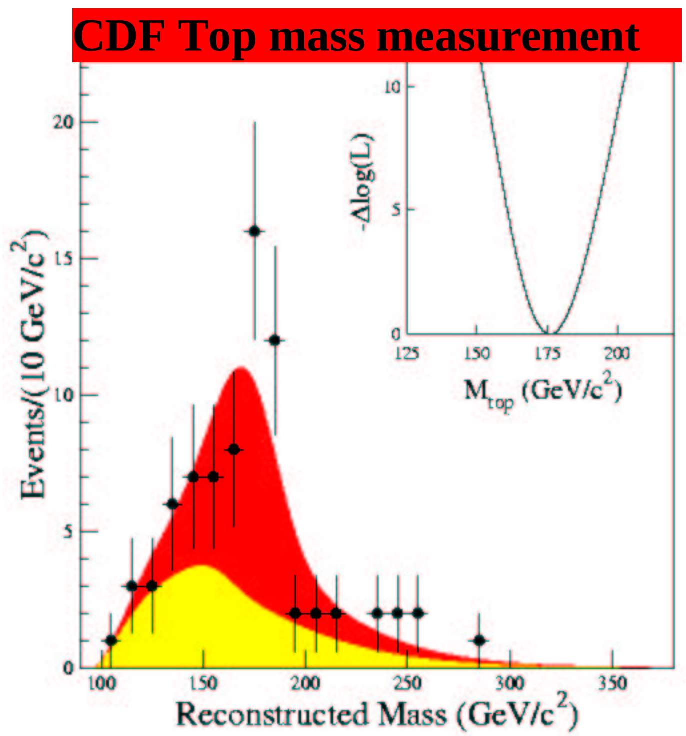


Top Quark property Measurements

Bachacou, Brubaker, Galtieri, Gibson, Kim, Lys, Volobouev, Yao

- Improved top mass measurement
- Single top production to measure V_{tb}
- Test validity of Standard Model with:
  - Top decay rates measurements in allowed channels
  - Angular correlations





Higgs search

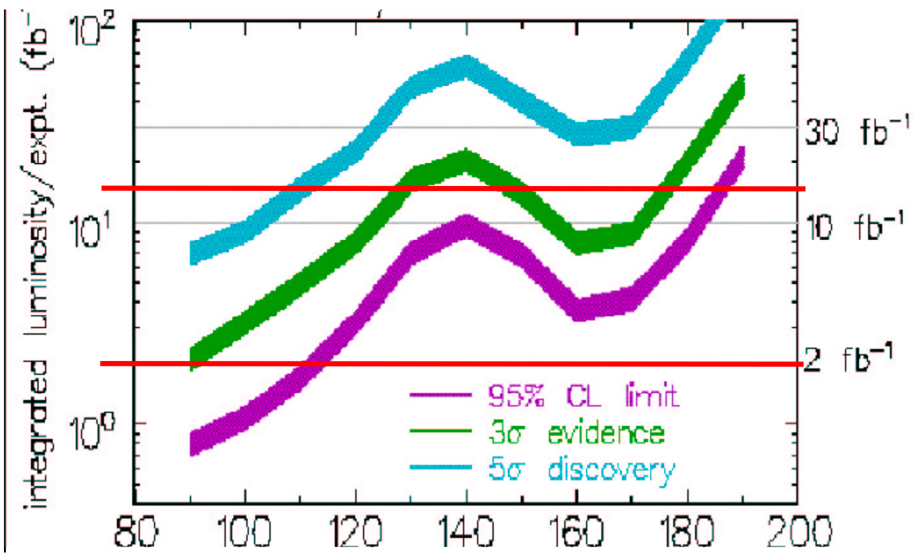
Yao (co−convener of the Higgs group), Dominguez, Nielsen, Reygadas

Standard Model Higgs needs large accumulated luminosity, improved jet resolution, understanding of backgrounds etc. Long range.

SUSY Higgs can have a large cross section for large values of tanβ. A modest luminosity can provide interesting limits.

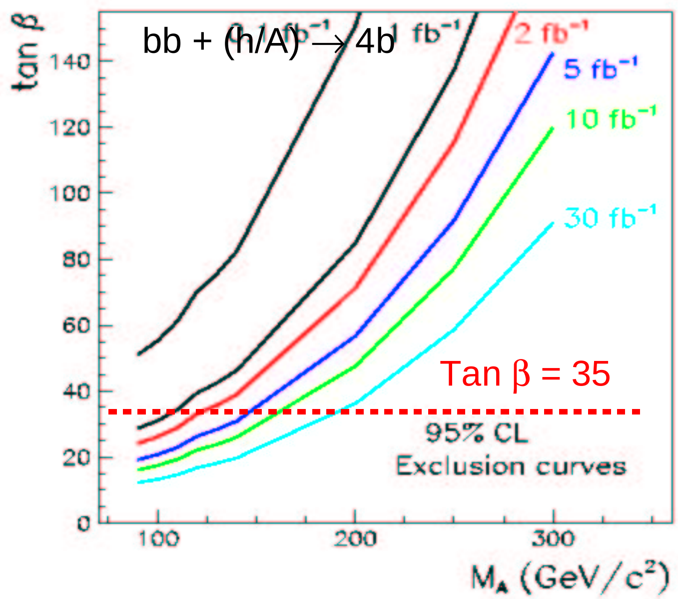
A/H $\rightarrow \tau\tau$, bb are the channels to study

LEP II Searches : M_{Higgs} > 113 GeV at 95%CL
LEP II Hint at Mh_{igg}= 115 GeV



Mh_{iggs} (GeV)

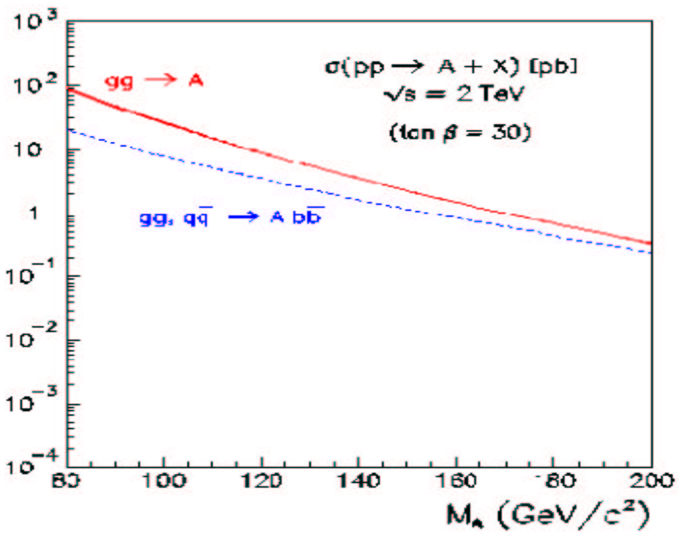
SUSY Higgs



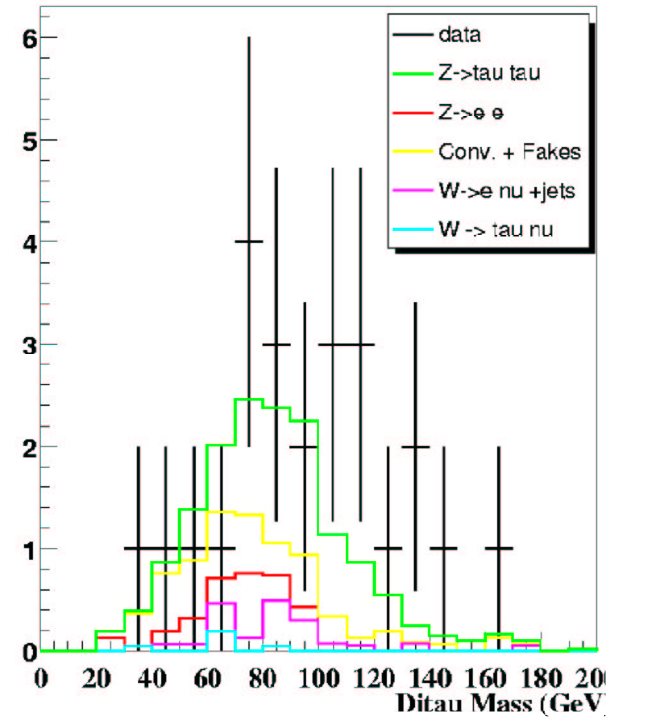
Run Ib Analysis: SUSY Higgs A/H in $\tau\tau$

Amy Connolly's Ph.D. Thesis

$\sigma(gg \rightarrow A/H) \sim \tan^2\beta$

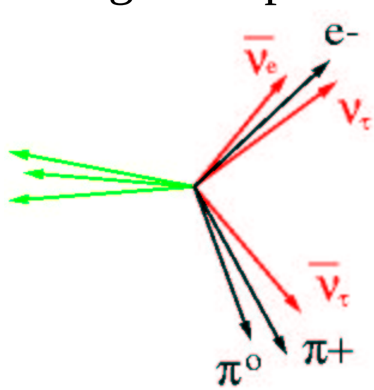


- Total number of events in the plot:
  - Expected: 17 ± 3 (syst)$\pm$ 4 (stat)
  - Observe: 24
- Reveals a previously unobserved Z $\rightarrow \tau\tau$ mass peak

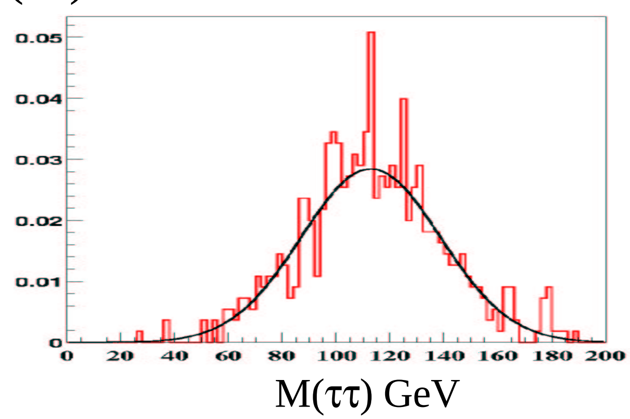


Run Ib data : high Pt lepton triggers

recoil jet



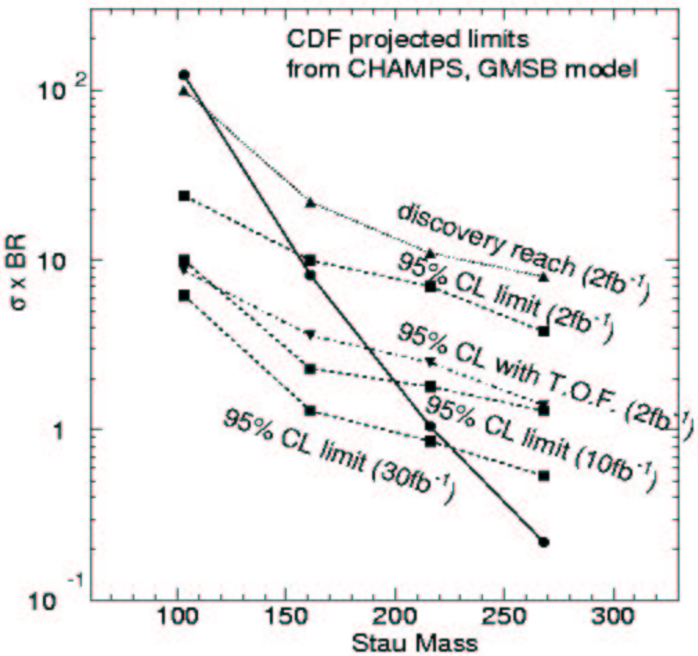
M($\tau\tau$) will be an essential discriminant.



Charged Massive long−lived Particles

Bill Orejudos

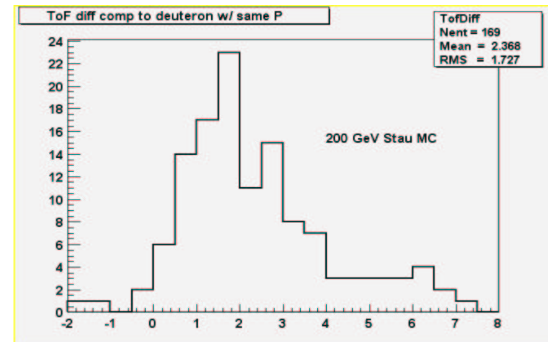
- CHAMP candidates
  SUSY: stable stau, stop



Stau mass

- 4^{th} generation quarks
- Implemented into MC
- **CHAMP property studies**
  - **Isolation, TOF, COT dE/dx**

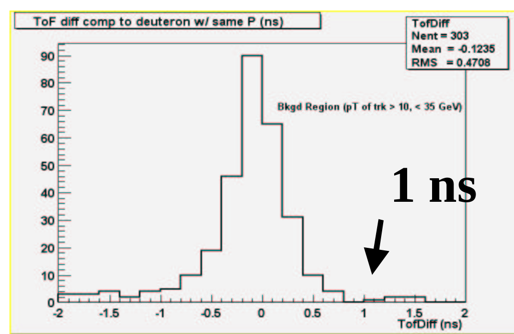
- Trigger proposed: L1 2−tracks above 35 GeV/c
- Analysis based on flight time for massive particles
- TOF difference for a CHAMP of 200 GeV and a deuteron (MC)



- Muon trigger used below: 5 pb^{-1} of data

Background region

CDF Preliminary

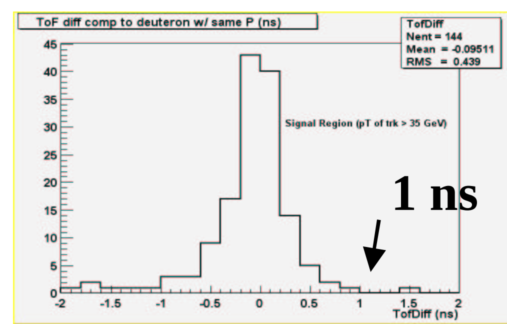


P_T track=10−35 GeV

Δt>1 ns 1.8 events

Signal region

CDF Preliminary



P_T track > 35 GeV/c

Δt>1 ns 1 event seen

Summary

- CDF LBNL group very busy, starting to look at physics in Run II.

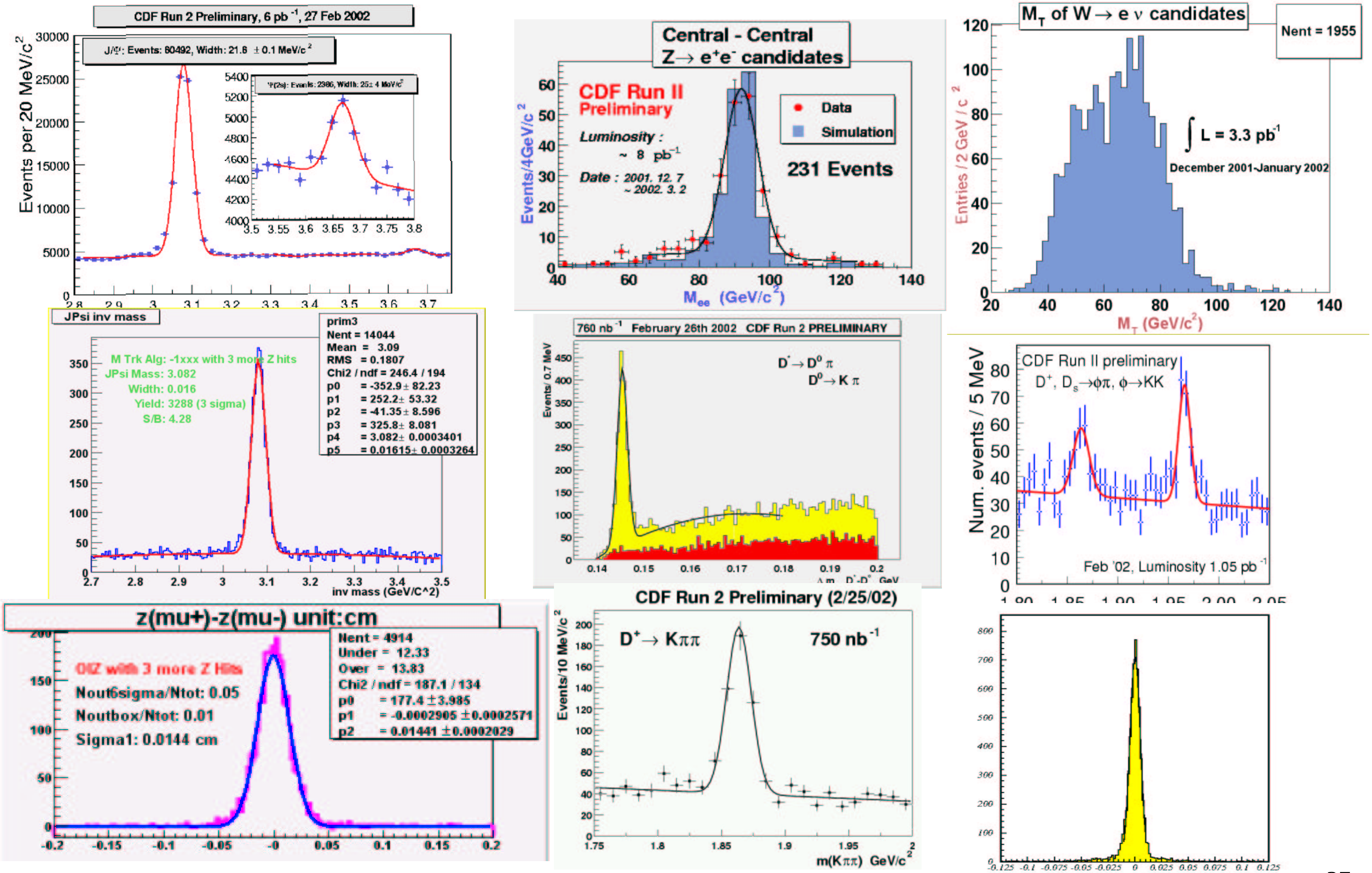
- Detector commissioning is almost at the end, except for ISL. We are still involved in studying and testing possible hypotheses for SVX3 chip failures especially in the high radiation environment.

- Tools for physics analysis being prepared:
  tracking, exploitation of the SVT trigger, electron ID,
  jet corrections, b−tagging, simulation tuning etc.

- Need more luminosity!!

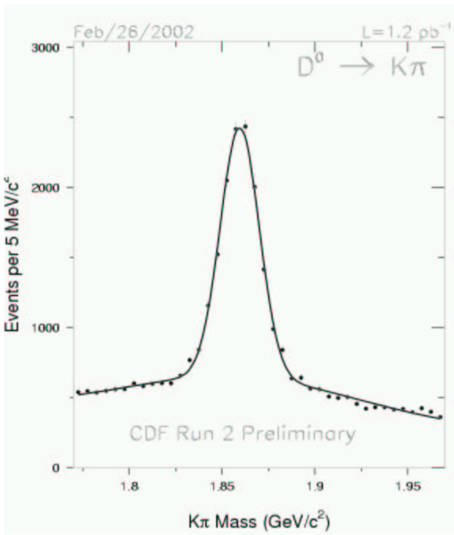
- Run IIb silicon detector work started in 2000.
  - SVX4 chip: full chip back in a month
  - Stave concept being tested
  - Hybrids prototypes in fabrication.
  - Hybrid production: need $$$

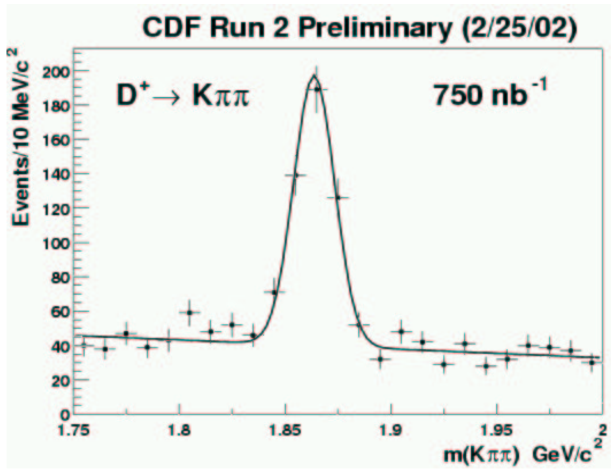
Very exciting times ahead

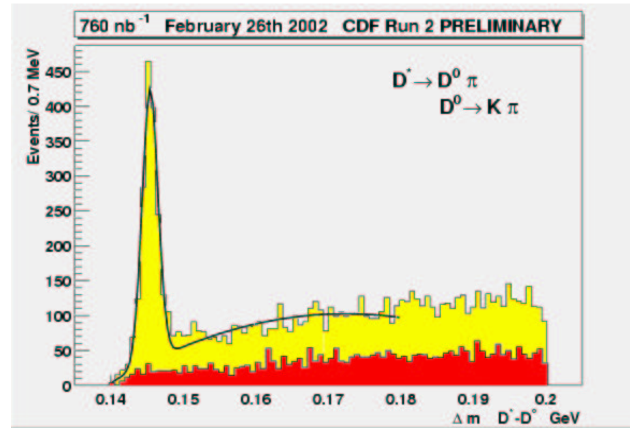


Charm Physics at CDF

From first pb^{-1} with the SVT:







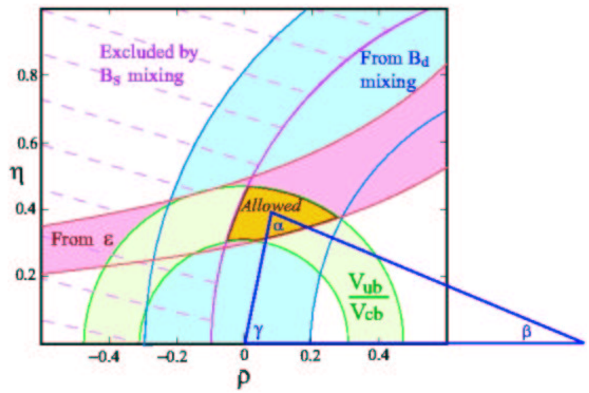
Large yield, but poor PID, biased trigger, prompt & secondary charm.

D^0 mixing: Lifetime difference between $D^0 \to K^-\pi^+$ and $D^0 \to K^- K^+$
Time−dependent analysis of wrong sign decay $D^0 \to K^+\pi^-$

CP violation: CP asymmetry in $D^0 \to K^- K^+$ $D^0 \to \pi^-\pi^+$ $D^+ \to K^-K^+\pi^+$
from tree−penguin interference in $c \to u q \bar{q}$ transition

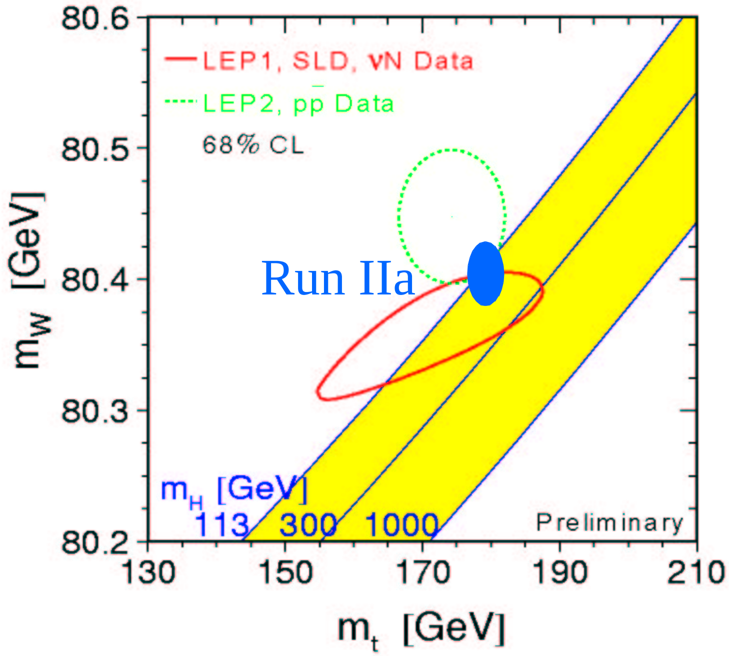
CDF Physics Prospects (very rich!)

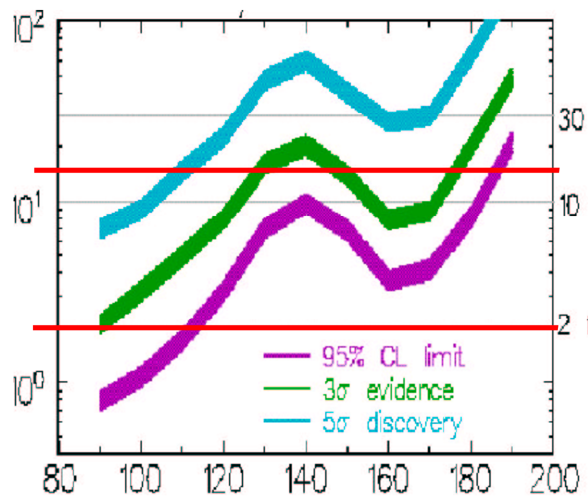
- B: CP violation and CKM matrix

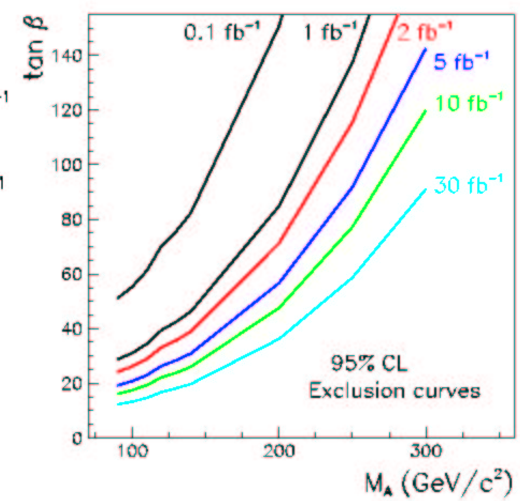


- B_S mixing
  - important for complete picture of the Unitary triangle.
  - unique at Tevatron
- sin2β

- Higgs







- W, Z, Top, B properties, SUSY searches, QCD up to 10^{-19} cm